Vol. XVIII. — No. 2. February 1936.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621. 133.5]

Improvements in the locomotive blast pipe,

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We dealt with the general working principles of the locomotive blast pipe in the July 1933 number of the *Bulletin of the International Railway Congress Association*, and called attention to the requirements to be met by a well designed blast pipe. We also gave the results obtained with a new blast pipe arrangement, the « Kylchap » or « K C » now fitted to over a thousand locomotives on various railways.

In this article attention will be called to certain particular features in the action of the blast pipe, and to the exceptional performances put up recently, partly due to the Kylchap exhaust, by the 4-8-0 class 4701-4712 rebuilt locomotives of the Paris-Orléans Railway, described in detail in the February and March 1935 numbers of the *Revue Générale des Chemins de fer*.

Variable blast pipes.

Statistics of the various designs of blast pipe, both variable and fixed, fitted on locomotives throughout the world, show that the percentage of *variable* blast pipes is negligible.

The interesting point is that this is the position after years of experience and although the variable blast pipe, either the moveable cone or the double valve type, the latter especially, has been used more or less systematically, since its introduction, on all locomotives on the European Continent.

The reason is that the variable blast pipe is only necessary when the blast pipe design is defective and does not automatically regulate the draught proportionally to the steam used. This defect, moreover, must be marked, as otherwise it can be overcome by care in firing without altering the blast pipe opening.

In actual practice most locomotives still fitted with a variable blast pipe *are worked as though the nozzles were fixed* because the drivers, once they have found the setting at which the engine steams most freely note this position, and take care not to alter it for fear the engine will not be turned to the best account.

Everyone with locomotive running experience knows that when an engine will not steam either through bad coal and the grate becoming choked with clinker, or through the blast for some reason being insufficient, the enginemen prefer to fire to suit and use the reserve supply of briquettes rather than reduce the blast pipe opening.

This practice is the result of expe-

rience which has shown that closing the blast pipe top so reduces the power developed by the engine that it is easier to time the train by careful firing than by varying the blast pipe opening. This is especially so with fast heavy trains. The blast pipe opening frequently cannot be reduced as the top has been choked by fusible ash just when the difficulty in making the boiler steam arises.

When examining the curves of figure A (fig. 9 of our first article), the only advantage of the variable blast pipe is seen to be the slight reduction possible in the draught at low or medium rates of work when the steam consumption curve of the exhaust lies slightly below the boiler output line. These curves in

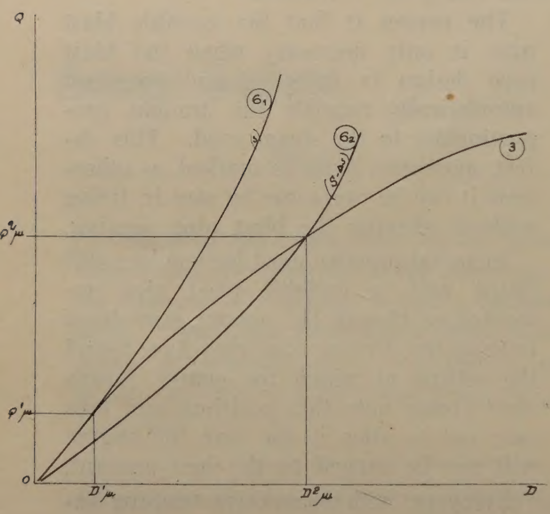

Fig. A.

practice are very flat so that for adjacent values (s) or (s-Δs) of blast pipe tops the boiler production may be reduced to a very low value Q^1_m, or on the contrary it may have a very different value Q^2_m at which it works normally. This state of things reduces the value of the variable blast pipe very much.

The only object in varying the opening is to be able to change at will from a curve such as (6_1), figure A, to another such as (6_2), or inversely.

As these curves lie very close together for actual rates of evaporation, the blast pipe opening can be altered effectively to an extremely restricted extent only. Moreover the resulting saving would be very small : even if the back pressure could be reduced by 20 to 30 %, the resulting increase in power or saving would be negligible, as the draught takes very little horse-power.

The reduction in back pressure becomes strictly necessary at high rates of working. The blast pipe, whether fixed or variable, must then have a sectional area in proportion to the rate of combustion required. This section only depends upon the *design of the blast pipe* quite independently of any question of variability.

To sum up, just when the variability of the blast pipe top could be effective it ceases to be required as the back pressure is no longer objectionable.

The reason why some engineers still believe in the variable blast pipe is that they have been deceived by the defects of certain blast pipe designs with which the draught is not proportional to the steam used and the variability becomes useful to correct an original and marked defect of the blast pipe. The variability of the blast pipe in such cases can correct the defects of the design, but the variation does not play the important part some of its partisans ascribe to it, i.e. the means of increasing the draught when needed to get the steam required under unexpected difficulties.

In order to make these explanatory remarks on the variable blast pipe clear, we will briefly refer hereafter to the results of the tests at the Altoona plant

on the K.4.S. and L-1-S locomotives of the Pennsylvania Railroad [1].

The ratio between the draught (weight of air exhausted per unit time) produced by the blast and the draught strictly necessary to ensure the coal being burnt only varied from 1.40 to 1.26 when the steam produced increased from 20 000 to 60 000 lb. per hour, i.e. 10 % only with a 3 to 1 increase in steam production.

The variable blast pipe can only effect this 10 % saving, and only at *light loads*. This clearly confirms, as suggested above, that variability is only effective with back pressures which do not matter and then only within narrow limits.

Equal distribution of the draught through the nest of tubes and the grate.

If the boiler is to work properly, especially when pressed, the draught must be uniform over the grate and through the tubes. With a single-nozzle blast pipe and no deflector [2] it is practically impossible to get the same evaporation from each tube, the draught in practice being concentrated through only a few of the tubes .

The result is that the draught under the grate is not the same over the whole area; clinker forms where the draught is light, and where the draught is heavy the fire is torn up as soon as the rate of combustion is increased.

These defects do not matter at low or medium powers and with good coal may even be unnoticed. Should the locomotive be called upon to develop its full power, with a smoke box vacuum of 200 to 400 mm. (7.85 to 15.7 inches) of water, evaporation becomes difficult, the efficiency of combustion falls off, and the tubes gradually choke up, which in turn makes evaporation difficult and at the same time causes the superheat to drop (from 320 to 270° C. = 608 to 518° F. for example), to the still greater detriment of the engine.

These drawbacks manifest themselves by the difficulty in making steam towards the *end of the run*. The variability of the blast has no effect on these conditions which can only be corrected by cleaning the fire and rodding the tubes, as soot blowers, or lances, are then useless.

These factors limit the power the locomotive can develop and the consumption increases to an unsuspected extent as soon as this critical moment is approached.

The use of *petticoats*, by multiplying the points of aspiration in front of the tube plate, from this point of view is a definite improvement over the designs with a single aspiration point.

With such designs of blast pipe when suitably proportioned to meet possible differences in the resistances to the gases in passing through the heterogeneous nests of tubes, the combustion is uniform over the whole grate and, other things being equal, the fire is not choked by clinker nor the tubes blocked by cinders.

The boilers will develop their full theoretical evaporative capacity without difficulty even at the end of the day's run.

The *Kylchap* blast pipe has been

(1) See *Bulletin No. 266 of the University of Illinois :* « A study of the locomotive front end (including tests of a front-end model) » By Everett G. Young.

(2) The deflectors in general use in America more or less correct the defects of the single blast pipe but at the price of much increased back pressure, owing to the excessive resistance to the passage of the gases past the deflector. The problem at high power is far from being solved by this arrangement which reduces the maximum power of the engine very considerably.

designed with special regard to this point and meets these desiderata particularly well. With it the maximum power of the boiler can be developed throughout the longest run (500 to 600 km. = 310 to 375 miles) and the fullest use can be made of the engines in consequence.

The fact that for the first time 1 200 kgr. of coal per m² (2 458 lb. per sq. foot) of grate has been burnt without excessive back pressure may well be stressed as this, in conjunction with proper steam passages, has made it possible to get from a locomotive double the power obtainable when other designs of blast pipe were used.

It has been found possible with this blast to get more power with a grate of 3.76 m² than from a 5.50-m² grate without it.

The consequences of using defective blast pipe designs.

The consequences of poor blast pipe design are much more serious than is generally thought.

As the locomotive forms a composite unit in which the working of any particular part depends on that of others, the defects of any one part can have serious consequences and result in serious losses of power with greatly increased fuel consumption.

For instance, when a Kylchap blast pipe on a compound superheated *Pacific* locomotive is replaced by a clover-leaf blast pipe with three jets and a single point of aspiration, increasing the back pressure two or three times for the same hourly rate of evaporation, the engine suffers not only from the increased back pressure but also from the appreciable drop in superheat (some 20° C. = 36° F. at low rates of power, increasing to 50° C. = 90° F. at full power) in consequence of the progressive obstruction of the tubes mentioned above.

With water rates of 20 m³ (4 400 Br. gallons) per hour when carrying out constant speed tests at 90 km. (56 miles an hour, at constant cut-offs with brake locomotives, the power developed at the drawbar was 1925 H.P. with a water rate of 10.27 litres (22.64 lb.) per H.P., (using an ordinary injector, fitted with Schmidt superheater) with the Kylchap blast pipe, as compared with 1 604 H.P. and a water rate of 12.82 litres (28.26 lb.) per H.P. with the ordinary blast pipe (clover-leaf).

The back pressure of 0.440 kgr. per cm² (6.24 lb. per sq. inch) in the first case rose to 1.110 kgr. per cm² (15.6 lb. per sq. inch) in the second. The coal per horse-power hour was 2.06 kgr. (4.54 lb.) with the ordinary blast pipe and 1.59 kgr. (3.50 lb.) with the Kylchap, or an increase of 29.5 % with 320 H.P. less than the maximum the type of locomotive considered (with Schmidt superheater and Kylchap blast) can develop.

Then too in this case, as the water level in the boiler could not be maintained with the ordinary blast pipe, advantage was taken of the lower back pressure and the lower rate of combustion due to using the heat stored in the boiler, to reduce the coal consumption very greatly.

Performances with 4-8-0 type high speed locomotive with 1.85 m. (6 ft. 53/64 in.) diameter coupled wheels of the 4701-4712 class, Paris-Orléans Railway (1).

The very fine work done by the 4701-

(1) See the February and March 1935 numbers of the *Revue Générale des Chemins de fer* for the description of these engines and their blast pipe, as well as for particulars of the trials they underwent.

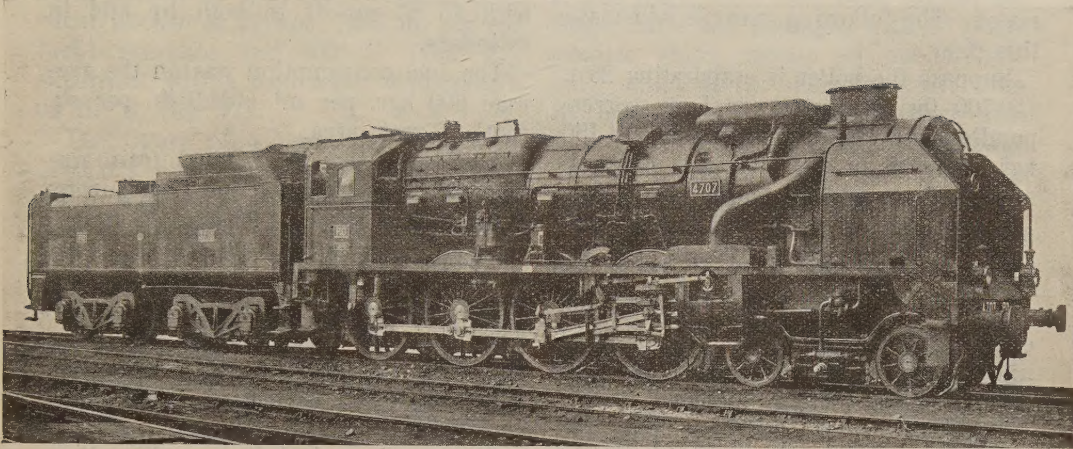

Fig. 1. — Paris-Orléans Railway class 4701-4712 eight-coupled bogie high-speed locomotive with large steam passages, high superheat, poppet valves, and Kylchap blast pipe.

Leading dimensions and characteristics.

Boiler pressure		20 hpz. (290 lb. per sq. inch).
Grate area		3.76 m² (39.5 sq. ft.).
Heating surface	Direct	24.90 m² (268 sq. ft.).
	Indirect	188.71 m² (2 031.3 sq. ft.).
	Total	213.61 m² (2 299.3 sq. ft.).
Superheating surface		67.02 m² (721.4 sq. ft).
Cylinder diameter, h. p.		440 mm. (19 5/16 in.).
Cylinder diameter, l. p.		640 mm. (25 1/4 in.).
Stroke		650 mm. (25 5/8 in.).
Diameter of driving wheels		1.850 m. (6 ft. 53/64 in.).
Adhesive weight in working order		76 400 kgr. (168 430 lb.).
Total weight, in working order		109 040 kgr. (240 390 lb.).

4712 class locomotives of the Paris-Orléans Railway must be dealt with in this note on blast pipes because it is largely due to the valuable features of the Kylchap double blast pipe with which these engines are fitted.

These locomotives, by maintaining an indicated H.P. of 3 800 and a drawbar horse-power of 3 000 with constant boiler water level, with a narrow grate 3.80 m. (12 ft. 6 in.) long, having an area of 3.76 m² (39.5 sq. feet), hold a record only made possible by the intense draught given by this blast pipe.

To use the full power of the engine, the coal consumption has to be some 600 to 1 200 kgr. per cm² (122.9 to 245.8 lb. per sq. foot) per hour, which in view of the small size of the boiler essential for a low weight to power ratio — the engine in working order weighs 109 tons — means high smoke box vacuum, increasing from 200 mm. (7.87 inches) when burning 200 kgr./m² (41 lb. per sq. foot) to 550 mm. (21.65 inches) of water when burning 1 200 kgr./m² (245.8 lb. per sq. foot).

As the back pressure is a function of the vacuum, the value of a well designed blast pipe in this case is easily appre-

ciated. The following example will make this clear.

Suppose the boiler is evaporating 23 t. (50 700 lb.) of water per hour corresponding to a rate of combustion of 1 150 kgr./m^2 (235 lb. per sq. foot) of grate area per hour with a vacuum of 510 mm. (20.08 inches) of water and a back pressure of 700 gr./cm^2 (9.96 lb. per sq. inch).

At 110 km. (68.35 miles) per hour the engine develops 2 900 H.P. on the level under these conditions and the draught requires some 290 H.P. thereof.

With the clover-leaf blast pipe the back pressure reaches 2 kgr./cm^2 (28.4 lb. per sq. inch); the draught requires 840 H.P. and the loss of power increases to 560. Instead of 2 900, the locomotive will only develop 2 340 H.P., i.e. only 80 %.

In this case the fitting of the Kylchap blast pipe results in a 24 % increase in drawbar horse-power.

The following results obtained with these locomotives are particularly interesting :

1. *Main-line tests with ordinary or special trains on the Orléans system.*

A train of 800 t. (787 Engl. tons) was hauled at an average speed of 90 km. (56 miles) an hour between Saint-Pierre-des-Corps and Angoulême (214 km. = 133 miles on a rising gradient of 1 in 200).

The drawbar horse-power (1) was 2 400 to 2 600.

The sustained speed was 95 km. (59 miles) an hour up 1 in 200 for an average drawbar horse-power of 2 500 with 45 % cut-off in both hp and lp cylinders.

The fuel consumption was on the average 600 kgr. per m^2 (122.9 lb. per sq. foot) of grate area.

A 730-t. (718.4 Engl. tons) train was worked between Vierzon and Châteauroux at an average speed of 90 km. (56 miles) an hour in spite of 1 in 100 gradients on the line in question.

The drawbar horse-power reached 2 600 and was maintained between 2 400 and 2 500 on the 1 in 100 gradient on which the speed was 80 km. (49.7 miles) an hour.

The speed reached 95 km. (59 miles) an hour on the 1 in 166 gradient with an average coal consumption of 750 kgr. (153.6 lb.) and an average drawbar horse-power of 1935.

An accelerated train of 575 t. (566 Engl. tons) was worked over the same line, the average speed being 98.9 km. (61.45 miles) an hour between Vierzon and Châteauroux and 97.6 km. (60.65 miles) an hour between Châteauroux and Limoges.

The speed on the 1 in 100 gradient was 85 to 93 km. (52.8 to 57.8 miles) and on the 1 in 166 gradient, 103, 108 and 112 km. (64.0, 67.1 and 69.6 miles) an hour. The indicated horse-power reached 4 000 and the drawbar H.P. 2 500 to 2 600. The hourly average rate of combustion was 800 kgr. (163.8 lb. per sq. foot), and the mean draw bar horse-power was 1893.

2. *Line tests with brake locomotives at constant speed and cut-off.*

Systematic tests carried out by this accurate method show that an evaporative power in cubic metres of more than 6 times the grate area expressed in square metres can be obtained with the 4 700

(1) The power as shown on the dynamometer and uncorrected for gravity or acceleration.

class engines on the Paris-Orléans, even when worked at 20 hpz. (290 lb. per sq. inch) pressure, and 400° C. (752° F.) superheat, with a feed water temperature of 10° C. (50° F.).

The figure of 4 times the grate area (Nadal's formula) has been considered up to now as a maximum, even in the case of saturated steam with much lower heat content than steam superheated to 400° C. (752° F.).

The usual maximum has therefore been increased by 50 %.

Finally these locomotives with only 3.76 m^2 (39.5 sq. feet) grate area have been able to maintain 3 030 drawbar H.P. at a speed of 100 km. (62 miles) an hour, consuming 7.5 l. (16.53 lb.) of water, and 1.29 kgr. (2.83 lb.) of coal per drawbar horse-power/hour.

The boiler pressure of these engines is 20 hpz. (290 lb.) but even at the usual pressure of 16 hpz. (232 lb. per sq. inch) they can easily maintain 2 500 to 2 750 H.P. at the drawbar at 90 km. (56 miles) an hour for a water consumption of 7.1 l. (15.65 lb.) and 1.10 kgr. (2.42 lb.) of coal per horse-power/hour.

Such consumption figures are exceptionally low *for such powers* and for an eight-coupled engine with relatively small wheels (1.85 m. = 6 ft. 53/64 in.). At lower powers and speeds these figures fell to 0.91 kgr. (2.0 lb.) with 2 500 H.P. at 90 and 70 km. (56 and 43.5 miles) an hour; to 1 kgr. (2.2 lb.) for 2 000 H.P. at 110 km. (68.35 miles) an hour; 0.87 kgr. (1.92 lb.) at 90 km. (56 miles) an hour; and 0.83 kgr. (1.8 lb.) at 70 km. (43.5 miles) an hour.

3. *Trials on special trains between Paris and Boulogne and Paris and Calais.*

Express trains of 750 to 760-t. (738 to 748 Engl. tons) have been worked between Paris and Boulogne with 15 intermediate stops, mostly of one minute only, which is too short to profit from the heat stored in the boiler. Each time the train is stopped and restarted a large quantity of steam is used, and this means the engine must steam well.

These trains, moreover, were steam-heated, but this did not appear to interfere with the evaporation.

On the run made on the 5th December 1934, from Paris (Le Landy) to Boulogne, the average speed was 80 km. (49.7 miles) an hour instead of the booked timing of 76.7 km. (47.7 miles).

The average drawbar horse-power developed was 2 150 between Le Landy and Amiens, and 2 015 between Amiens and Boulogne.

The average between Le Landy and Chantilly was 2 365, and between Clermont and Saint-Just 2 360. *The Survilliers gradient was climbed at 110 km. (68.35 miles) an hour from Goussainville,* with a drawbar horse-power of 2 500 to 2 800. Figures 2 and 3 show how this train was worked.

On the return run, on the 8th December 1934 (figs. 4 and 5), the drawbar horse-power exceeded 3 000 on the 1 in 133 rising gradient between Boulogne and Etaples.

On the 28th November 1934, the section Amiens to Saint Just was covered at an average speed of 102 km. (63.4 miles) an hour and the sustained power developed up the whole gradient was 2 600 H.P. (cut-off hp 43 %, lp 48 %).

The train passed Gannes at 117 km. (72.7 miles) an hour on the 1 in 250 gradient.

Heavy trains (646 t. = 635.7 Engl. tons) have also been worked at high

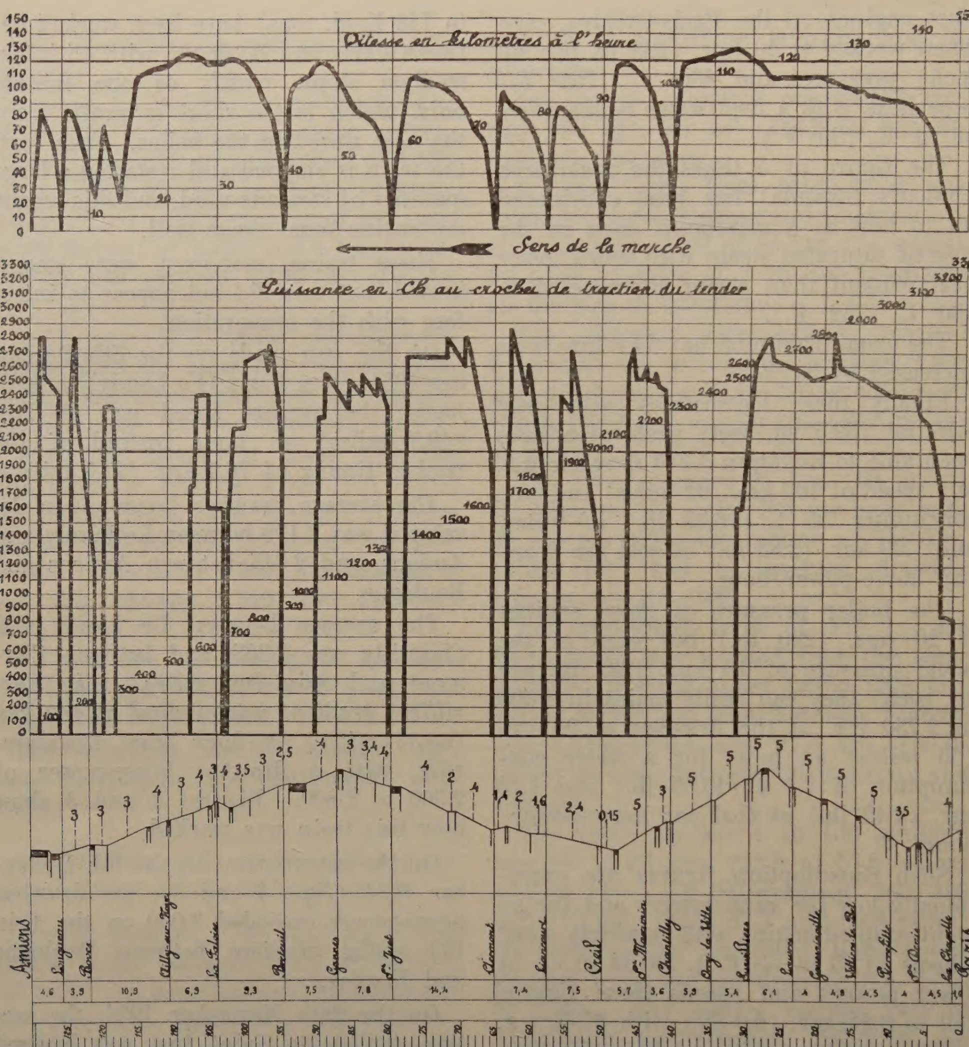

Fig. 2. — Special train OR-9, 5th December 1934, worked between Le Landy and Boulogne, by locomotive No. 4707.
Distance : 252 km. (156.6 miles). — Load hauled : 17 carriages, 759 t. (747 Engl. tons).
Section : Le Landy-Amiens.

Note : Vitesse ..... = speed in kilometres per hour. — Sens..... = direction of running...... — Puissance = tender drawbar horse-power.

speeds between Paris and Calais Maritime (297.5 km. = 184.9 miles).

For test purposes the maximum authorised speed was raised to 140 km. (87

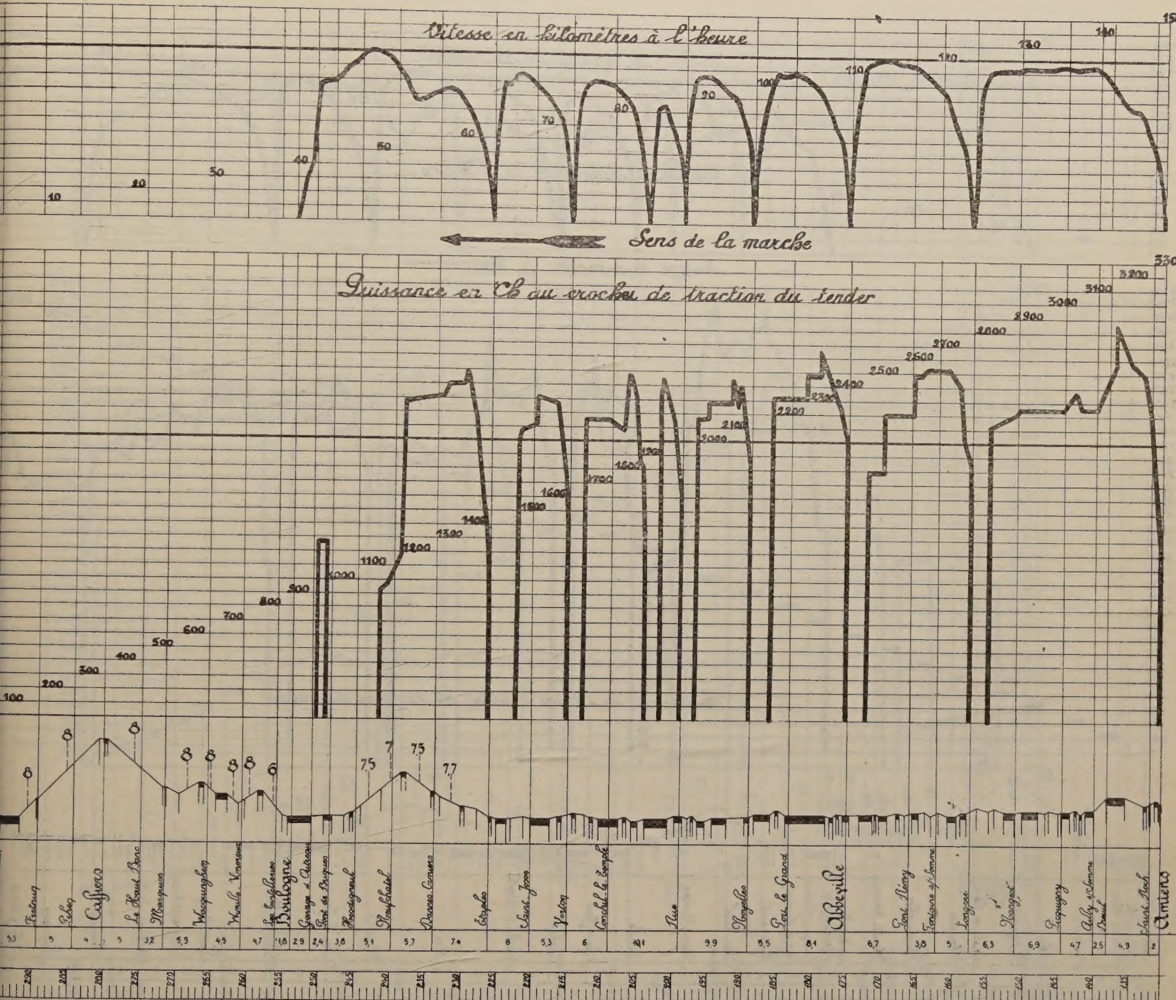

Fig. 3. — Special train OR-9, 5th December 1934, worked between Le Landy and Boulogne by locomotive No. 4707.
Distance : 252 km. (156.6 miles). — Load hauled : 17 carriages, 759 t. (747 Engl. tons).
Section : Amiens-Boulogne.

miles) an hour. A first run was made non-stop in 2 3/4 hours, i.e. at an overall speed of 108 km. (67.1 miles) an hour.

A speed of 142 km. (88.2 miles) an hour was reached at the Chantilly viaduct.

The following runs were made with the trains steam-heated and a stop at Amiens for water.

On the 18th February 1935 the run Paris-Nord to Calais-Maritime (294 km. = 182.7 miles) was covered at a commercial speed (including the Amiens stop) of 110 km. (68.35 miles) an hour,

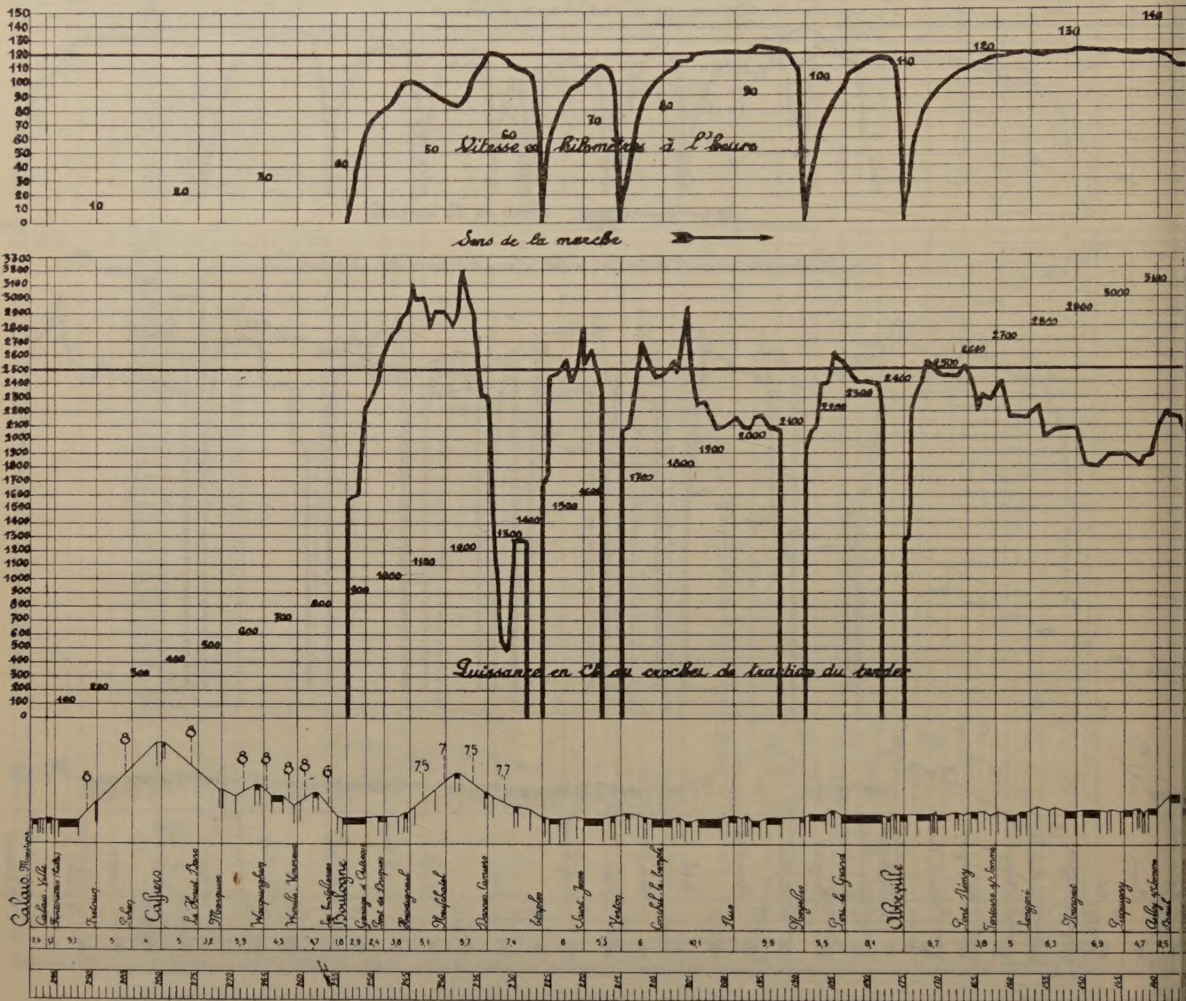

Fig. 4. — Special train OR-8, 6th December 1934, worked between Boulogne and Le Landy by locomotive No.

Distance : 254 km. (157.8 miles). — Load hauled : 17 carriages, 759 t. (747 Engl. tons).
Section : Boulogne-Amiens.

and deducting the stop at Amiens in 2 h. 21 m. or at an average speed of 117 km. (72.7 miles) an hour.

A speed of 140 km. (87 miles) an hour was easily maintained on the level section 100 km. (62 miles) long between Amiens and Etaples.

The drawbar horse-power varied between 2 000 and 2 100 and the cut-offs were 30 % in hp and 40 % in lp. Fi-

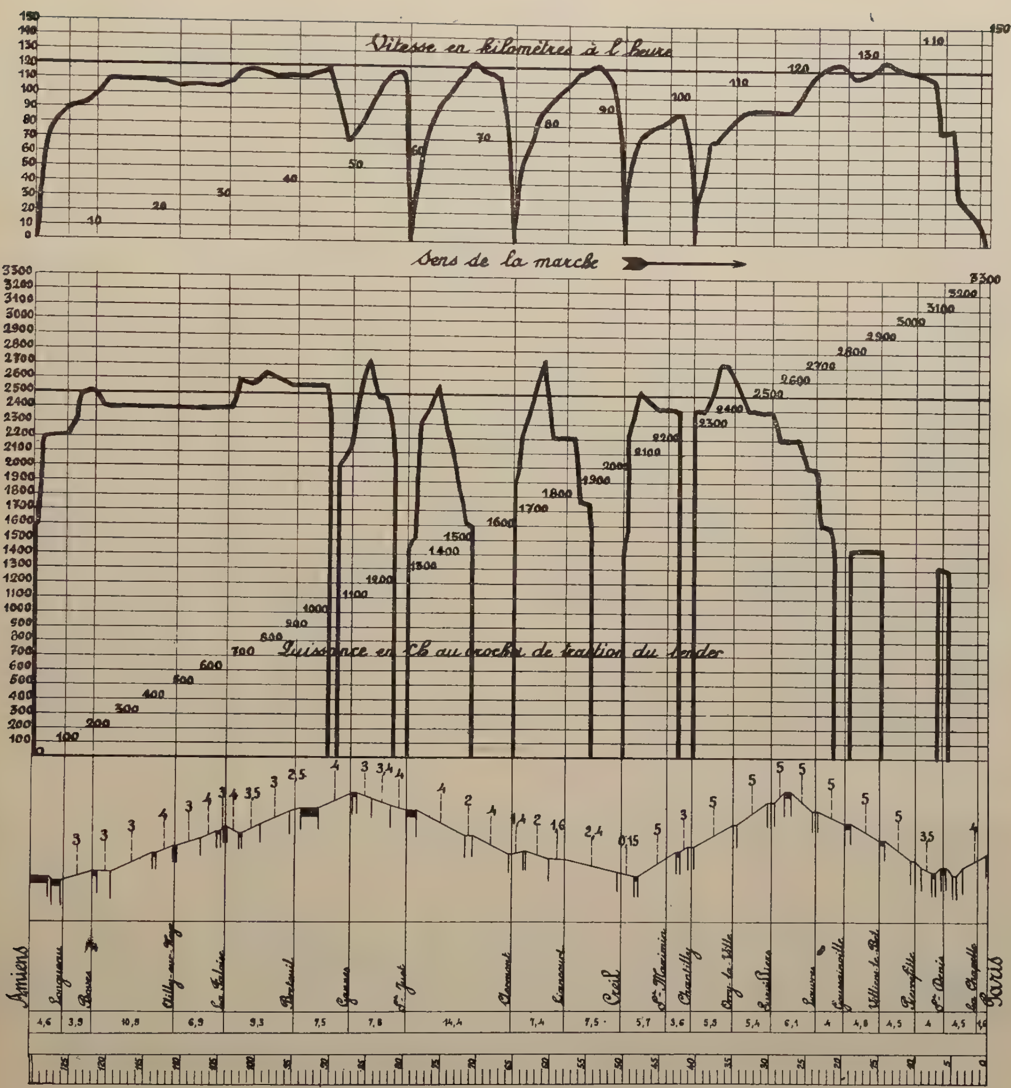

Fig. 5. — Special train OR-8, 6th December 1934, worked between Boulogne and Le Landy by locomotive No. 4707.

Distance : 254 km. (157.8 miles). — Load hauled : 17 carriages, 759 t. (747 Engl. tons). Section : Amiens-Le Landy.

gures 6 and 7 show the running of these trains.

On the return run, deducting the stop at Amiens, the time taken to run from Calais-Ville to the junction at Le Landy (291 km. = 180.8 miles) was 2 h. 24 m.

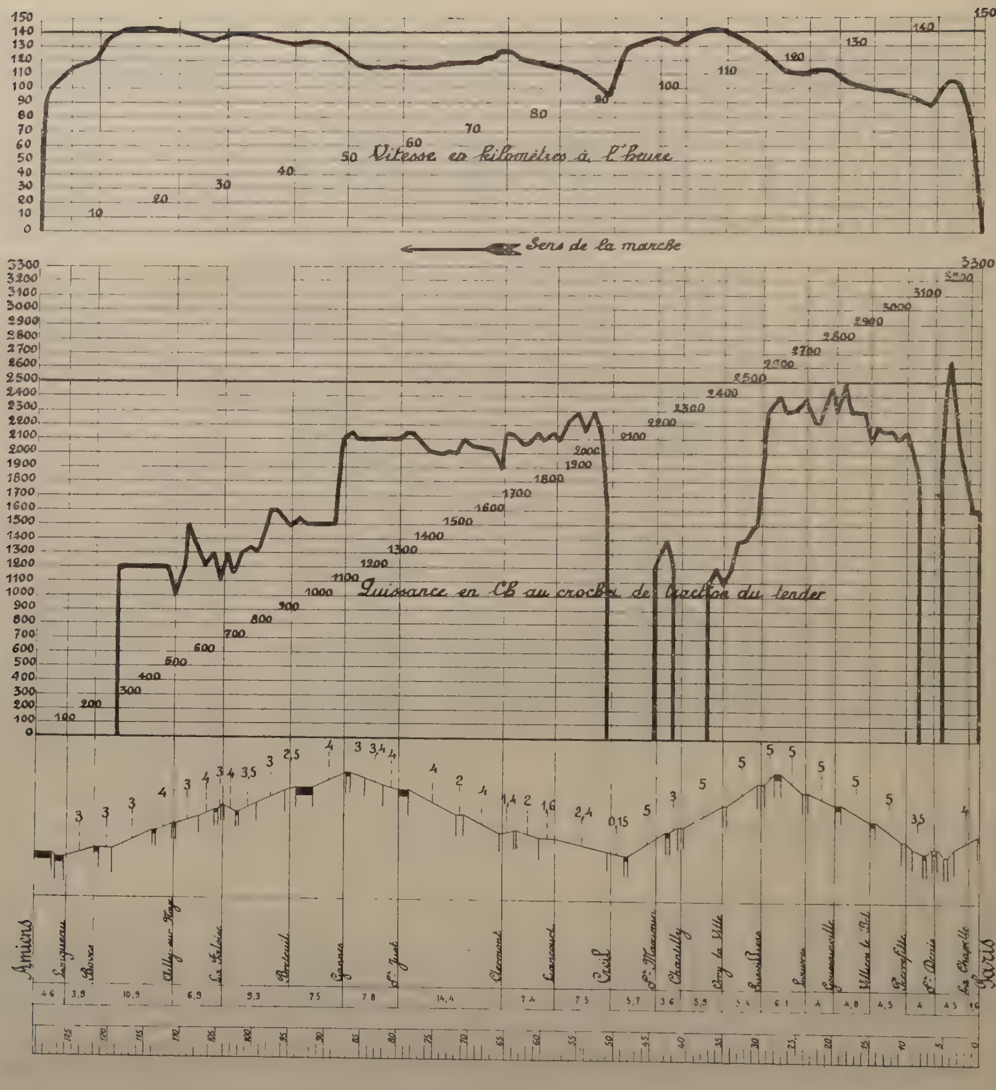

Fig. 6. — Special train O-A1, 18th February 1935, worked between Paris-Nord and Calais-Maritime by locomotive No. 4707.

Distance : 297.5 km. (184.9 miles). — Load hauled : 14 carriages, 646 t. (635.7 Engl. tons). Section : Paris-Amiens.

or an average speed of 121 km. (75.2 miles) an hour. The speed reached 147 km. (91.3 miles) an hour at Goussainville.

4. *Trials with special trains between Paris and Cherbourg.*

Heavy express trains [607 t. (597.3 Engl. tons)] have been worked between

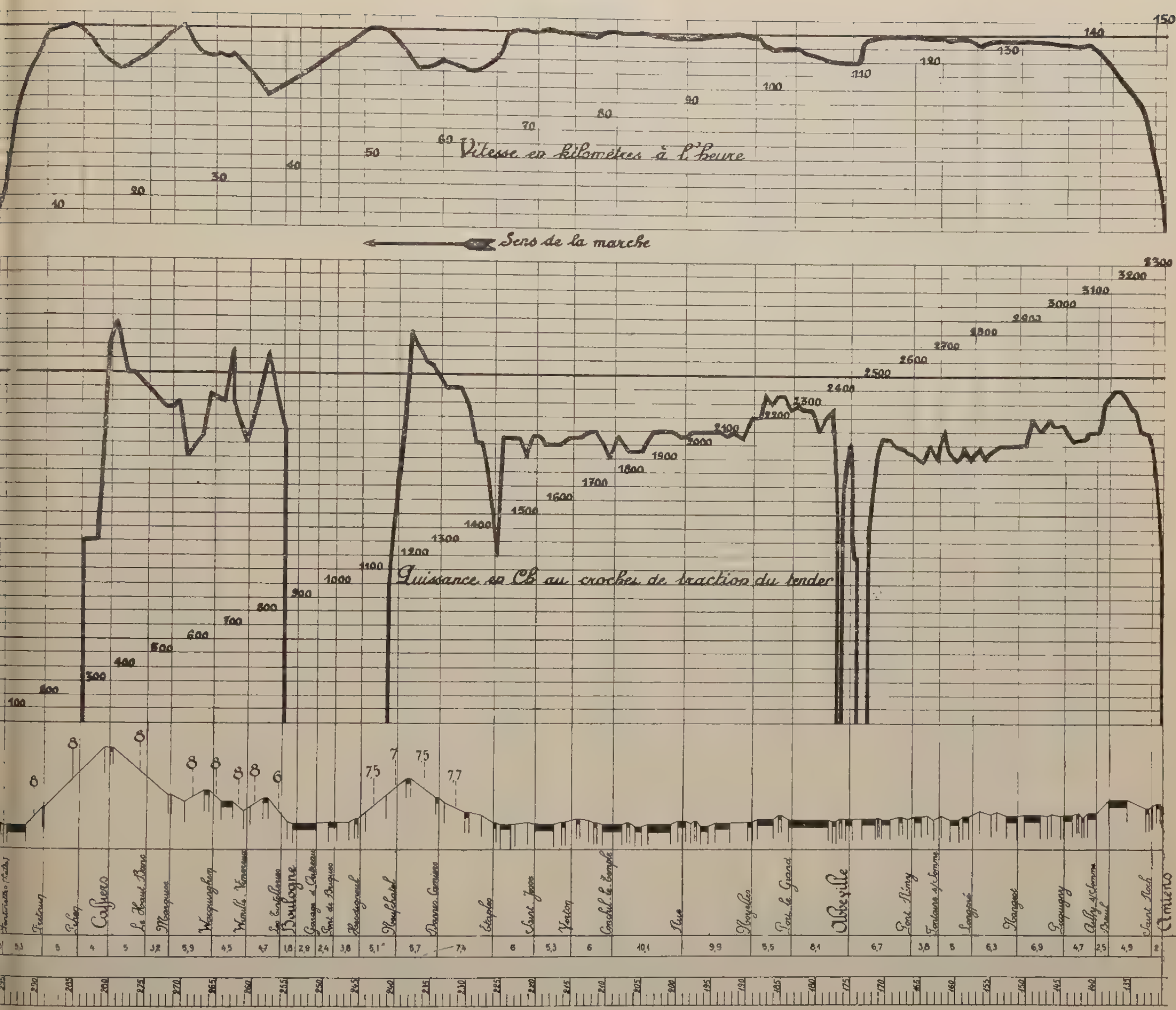

Fig. 7. — Special train O-A1, 18th February 1935, worked between Paris-Nord and Calais-Maritime by locomotive No. 4707.

Distance : 297.5 km. (184.9 miles). — Load hauled : 14 carriages, 646 t. (635.7 Engl. tons). Section : Amiens-Calais.

Paris and Cherbourg (370 km. = 229.9 miles) with the same locomotive No. 4707 used during the trials on the Nord System.

As the diagrams figures 8, 9 and 10 show, the line is difficult as there are many gradients of 1 in 166 to 1 in 100.

The run was made on the 21st March 1935 in 3 h. 28 m. deducting stops and speed restrictions, at an average overall

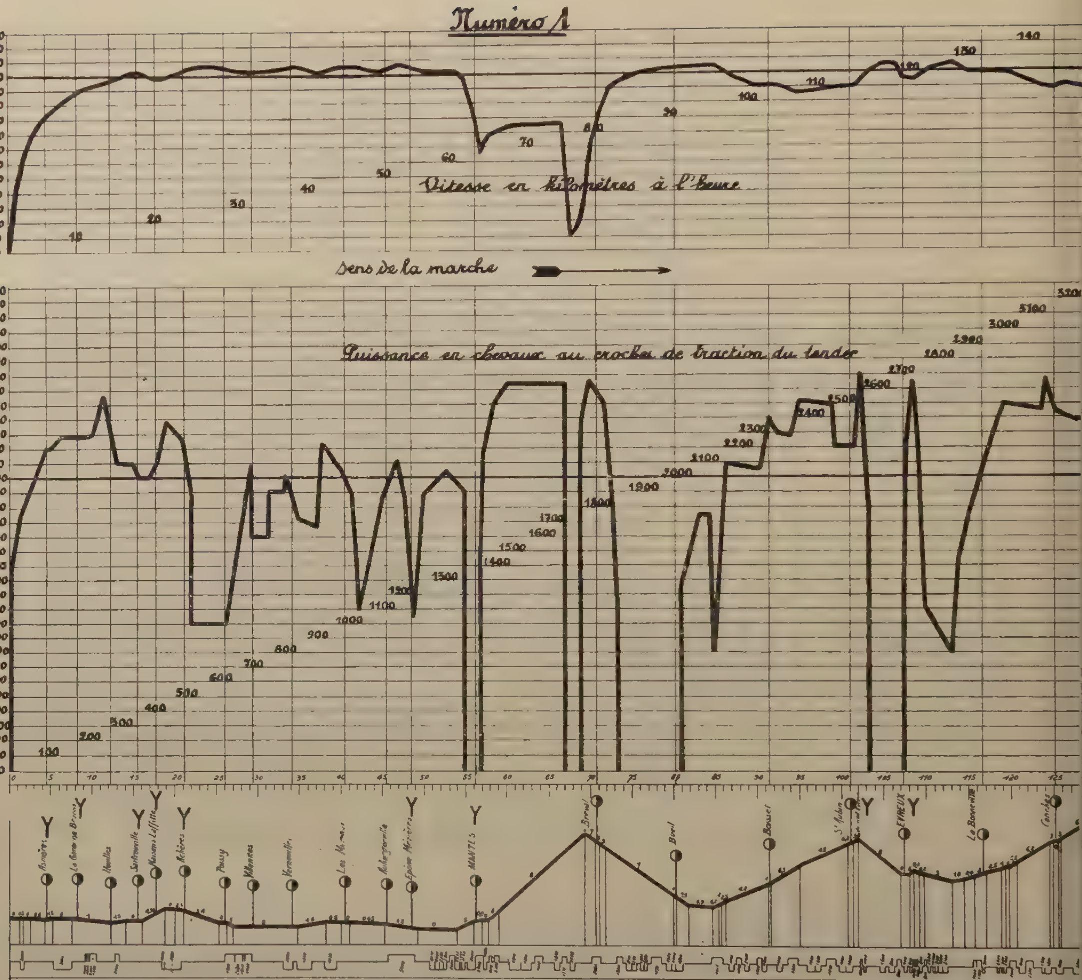

Fig. 8. — Special train No. 553, 21th March 1935, worked between Paris-St.-Lazare and Cherbourg by locomotive No. 4707.

Distance : 370 km. (229.9 miles). — Load hauled : 14 carriages, 607 t. (597.3 Engl. tons).

speed of 105 km. (65.25 miles) an hour (6-minute stop at Caen) or an average running speed of 107.8 km. (67 miles) an hour.

As the curves of figures 8, 9 and 10 show, the gradient from Mantes to Bréval (1 in 111), after the speed restriction of 65 km. (40.4 miles) an hour at Mantes, was climbed at a steady speed of 85 km. (52.8 miles) an hour. The sustained drawbar horse-power was 2 630.

The top of the Bernay gradient was passed at 100 km. (62 miles) an hour, the drawbar horse-power being 2 950.

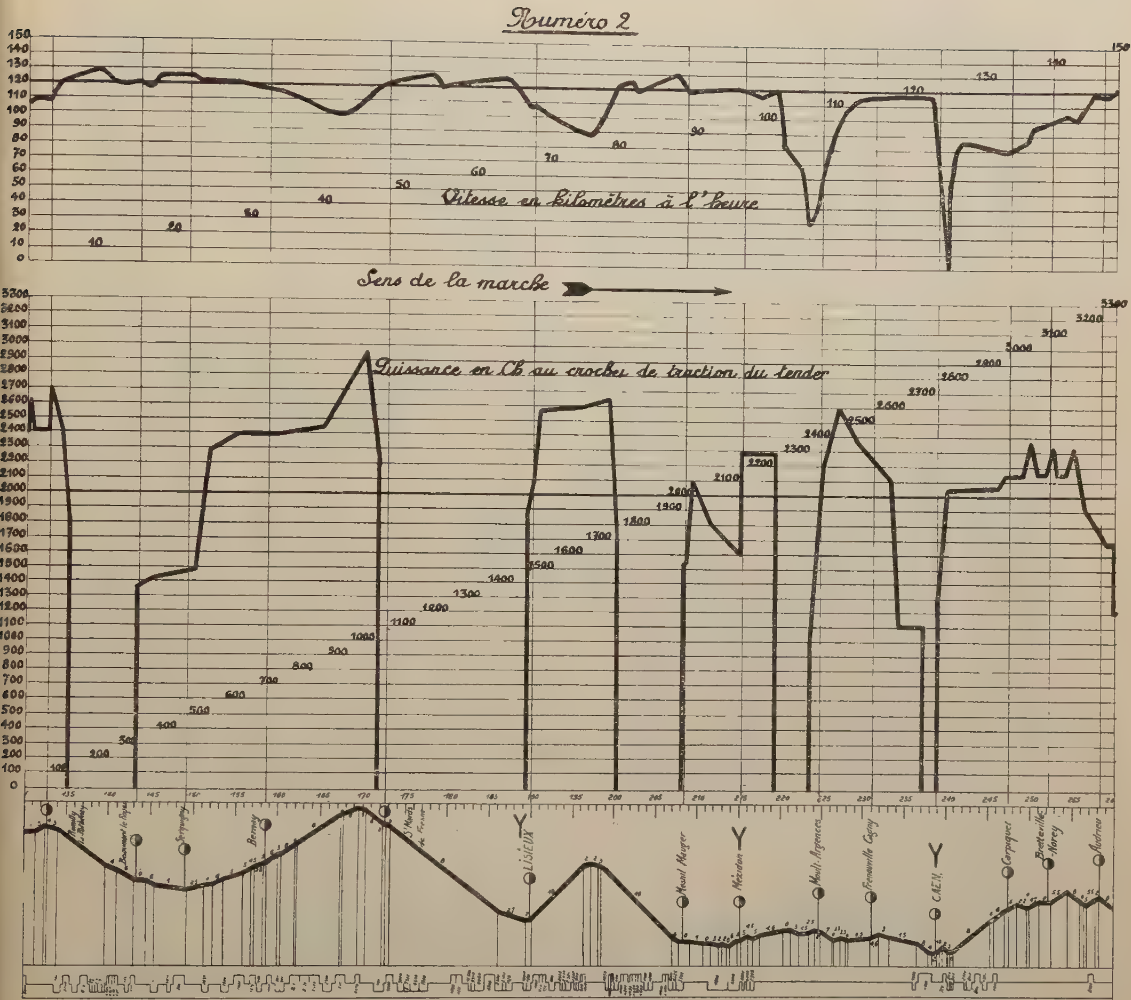

Fig. 9. — Special train No. 553, 21st March 1935, worked between Paris-St.-Lazare and Cherbourg by locomotive No. 4707.

Distance : 370 km. (229.9 miles). — Load hauled : 14 carriages, 607 t. (597.3 Engl. tons).

The top of the Lisieux gradient (1 in 100) was passed at 90 km. (56 miles) an hour, the drawbar horse-power having risen from 2 580 at the foot of the gradient to 2 640 at the top.

The speed over the top of the Couville gradient (1 in 118) was 102 km. (63.4 miles) an hour with a drawbar horse-power which had risen from 2 400 to 2 800.

In the Paris-Cherbourg direction, the 1 in 100 gradient from Cherbourg to 2 km. (1.2 miles) beyond Couville, including restarting on the gradient,

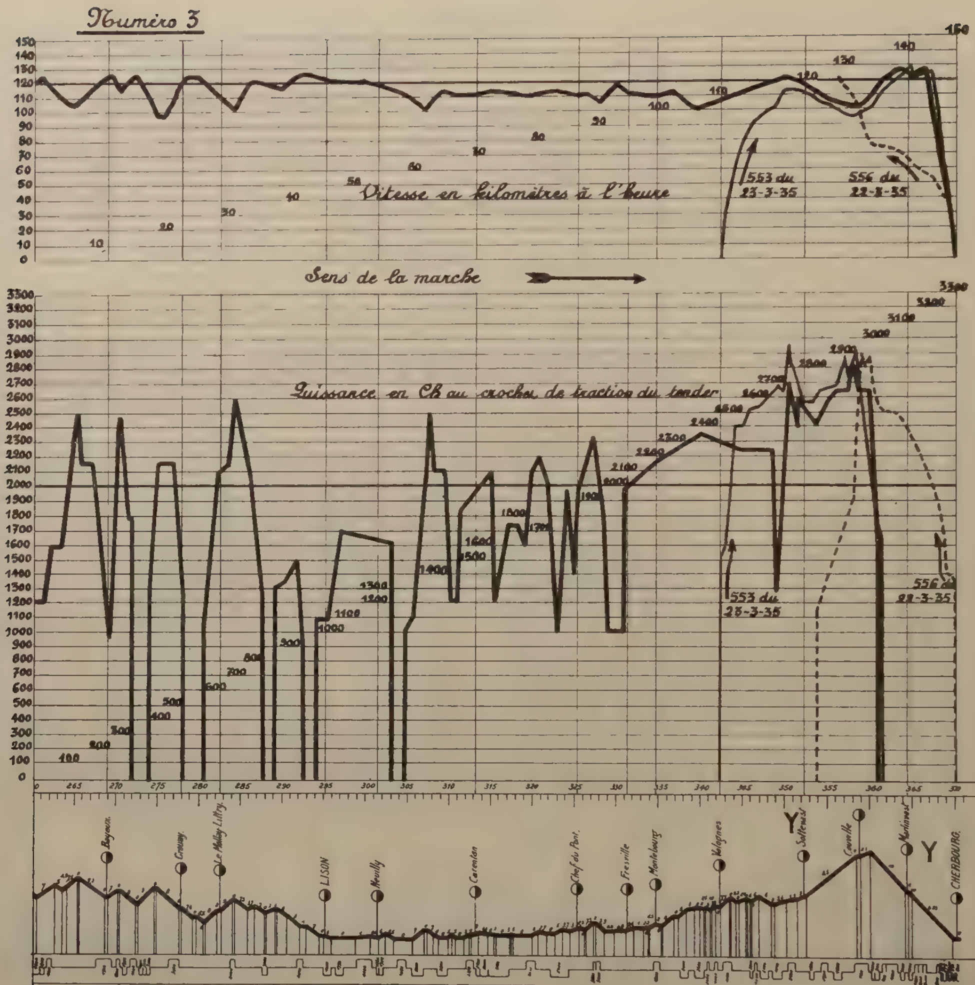

Fig. 10. — Special train No. 553, 21st March 1935, worked between Paris-St.-Lazare and Cherbourg by locomotive No. 4707.

Distance : 370 km. — Load hauled : 14 carriages, 607 t. (597.3 Engl. tons).

- - - - - - Train 556, 22nd March 1935, 607 t. (597.3 Engl. tons) Cherbourg-Paris.

——— Train 553, 23rd March 1935, 607 t. (597.3 Engl. tons) Paris-Cherbourg.

was topped at 75 km. (46.6 miles) an hour, the drawbar horse-power being 2 900 (the trailing load being 607 tons).

In spite of the difficulty in working these trains the consumption per drawbar horse-power hour was very low and varied from 1.2 kgr. to 1.43 kgr. (2.65 to 3.15 lb.) of coal, the usual figure being 1.25 kgr. (2.76 lb.) with from 7.86 to 8.26 l. (17.32 to 18.21 lb.) of water.

As during the Nord and Paris-Orléans tests, smoke box vacua of 400 to 450 mm. (15.75 to 17.7 inches) of water were required frequently and for long periods, and for peak loads 500 mm. (19.68 inches). The corresponding rates of combustion were 1 000 to 1 200 kgr. per m^2 (204.8 to 245.8 sq. foot) of grate area per hour.

In spite of working at such high rates *the engine entirely consumed its smoke.* The only trace of smoke seen was after firing just when closing the firebox door. The draught therefore, even under such exceptional conditions, is still quite sufficient.

The Kylchap blast and other new types.

The excellent results obtained with these Kylchap blasts, the *fixed* type of which is used at the present time on over 2 500 French (Paris-Orléans—Midi, Alsace-Lorraine, Nord, State, and Colonies) and foreign (Belgian, London & North Eastern Ry., Southern Ry., and London Midland & Scottish Ry., British Dominions, Rumania, Poland, etc.) locomotives, was fitted either during construction or during the trials to such noteworthy locomotives at the 60-atm. (853 lb. per sq. inch) pressure 2-6-2 Winterthur locomotive, the Cock O' the North of the L. N. E. R., the Franco locomotive, and this has induced some railways to design blast pipes more or less on the same lines.

Amongst such designs the blast pipe fitted to the 2-8-2 type 214-01 Austrian locomotives is almost identical and gives good results.

The variable blast pipe with cross bars, petticoat, and double chimney, fitted to the Paris-Lyons-Mediterranean 4-8-2-C-1, 4-6-2-H, 4-6-2-G, and 2-10-2-A type locomotives repeats the layout of the double Kylchap blast with the slight difference that the short V bars are replaced by cross bars and the Kylälä tubes by cylindrical petticoats.

The earlier tests to ascertain the advantages of the Kylälä tube over an American petticoat above the blast pipe nozzle were described in the article published in the July 1933 *Bulletin*, and showed the improvement given by the Kylälä arrangement.

The Nord-Belge has also tried a blast pipe derived from the type 1 K/T Kylchap but in which the Kylälä tube is made in one with the blast pipe nozzle.

This gives a multiple-jet blast of the kind tested years ago, which theoretically provides a certain degree of variability as one of the jets can be closed or reduced as required.

This variability is very small in some designs, as only 1/6th of the total area is affected, seeing that there is a ring of five nozzles with a central nozzle, the latter being the only one which can be closed.

Actually the variability obtainable is extremely doubtful, as when the central nozzle is closed the chimney, as might be expected, is no longer efficient.

This blast pipe design, when compared with the Kylchap, has the further defect that the suction does not take place across the tube plate at different levels, and the gases cannot get away between the nozzle and the base of the intermediate petticoat or tube.

The defects already noted in the original single blast pipe are therefore found in these latter designs as well.

Comparative study of road motor transport regulations

(*Continued*),

by VLADIMIR IBL,

Engineer, Manager of the Czechoslovak State Road Services.

We think it opportune to supplement the enumeration of the legislative or administrative enactments published in the May 1935 *Bulletin*, which formed the first part of this study, before proceeding with our first chapter. In this way not only can certain errors be corrected but the enumeration can be completed by interesting information collected since the first part was published.

* * *

Enumeration of the legislative or administrative enactments of the different European countries relating to road motor transport.

(Supplement).

Germany.

Point 1 (page 544) is to be completed as follows :

« On the 1st April 1936, however, the *law on long-distance road motor goods transport* of the 26th June 1935 (Gesetz über den Güterfernverkehr mit Kraftfahrzeugen) comes into force. The provisions of this law replace the above-mentioned order of the 6th October 1931 and also only deal with professional transport. This new law requires the setting up of an association of these hauliers.

Note. — The law of the 4th December 1934 (see point 1, page 544) came into force on the 1st April 1935.

Point 4. (pages 544 and 545) should be reworded as follows :

« The *taxes* on motor vehicles are in future governed by the law *as published in its latest form on the 23rd March 1935*, and put into force on the 1st April 1935. The administrative *decree enforcing* it was dated the *5th July 1935*. These two legal instruments codify and replace most of the earlier enactments.

* * *

Austria.

Point 4 (page 545) should read as follows :

2° *Order No. 253 of the 9th June 1933 on goods road transport* (Lastkraftwagenverkehrsverordnung) fixes the minimum rates to be charged by public road goods services, and as regards goods transport by lorries belonging to private individuals and carried out on their own behalf (Werkverkehr), it lays down that such transport cannot be carried out over distances exceeding 100 km. (62 miles) if they can be carried economically by rail.

This order was to remain in force until the 30th June 1934 and was amended by *orders No. 553 of the 7th De-*

cember 1933 and *No. 151 of the 22nd February 1934.*

Law No. 85 of the 15th June 1934 prolonged the period of application of order No. 253 above to the 31st December 1934, and law *No. 426 of the 6th December 1934* again postponed it to the 30th June 1935.

Point No. 6. (pages 545 and 546) is to be altered to read :

6° The general responsibility of the owners and operators of road motor vehicles is regulated by the old Austrian law No. 162 of the 9th August 1908, as supplemented by *orders No. 220 of the 23rd October 1908, No. 221 of the 26th October 1908 and No. 222 of the 28th October 1908* and revised by the *Federal law No. 300 of the 3rd May 1933* (Kraftfahrzeug Haftpflichtgesetz).

Finally there is a correction to be made on page 545 in the 3rd paragraph, point 1 : the number of the order of the 8th December 1931 should be *403* instead of *463*.

Belgium.

The wording of the last but one paragraph of point 4 (page 547) should be replaced by the following text :—

The provisions of the earlier orders were, however, modified and partly abrogated by the *law of the 30th December 1933*. The increased taxation on motor vehicles introduced by the first of these orders was much reduced, but was on the other hand extended to lorries exclusively used for transport on behalf of a third party, such lorries being, however, exempted from the new taxes on public goods transport by road.

The *royal order of the 16th January 1934* on the taxation of transport was in addition to the above regulations.

The new *royal order No. 72 of the 25th January 1935* dealing with the legal provisions relating to the taxation of motor cars and other vehicles with motor or steam engines simplifies the procedure without however modifying to any appreciable extent the total taxation to be paid by the users of such vehicles.

This order rescinded certain clauses of the law of the 28th March 1923 and subsequent laws; it abolished the order of the 14th August 1933 and the first three clauses of the law of the 30th December 1933.

France.

The following is to be added to point 1 (page 548) :

The decree of the 19th April 1934 set up in the Ministry of Public Works a Co-ordination Committee, to ensure the object of the decree — compulsory co-ordination of railway and road transport — being attained.

The Committee drew up proposals which were ratified by the *decree of the 25th February 1935 dealing with the administrative regulations* in connection with the co-ordination of railway and road transport (General regulations and passenger transport).

This decree, in section I, deals with the setting up and working of the *organisations* required to carry out this co-ordination, i.e. the technical departmental passenger and goods transport committees. Chapter IV of this section and sections II and III are devoted to *passenger transport.*

Section II of the decree lays down the requirements with which such transport agreements must comply before being approved by the Co-ordination Committee.

Section III is devoted to the obligations imposed on all public passenger motor services. It also lays down the sanctions and penalties to which operators failing to comply with the law are liable.

The agreements, many of which had already been prepared by the railways, will be actively proceeded with on the basis of this decree.

Goods transport is controlled by the decree of the 13th July 1935. So far as the working of the Co-ordination Committees is concerned, this decree is based on the provisions of that of the 25th February 1935 and its object is the preparation of plans for the distribution of public goods transport between the railways and the roads, private transport being explicitely excluded from its scope.

Section I of this decree defines the different classes of transport it covers or excludes; Section II deals with the census of public goods transport vehicles; Section III relates to the organisation of public goods services and in particular to their division between road and rail; Section IV contains provisions on the insurance policies road transport firms have to take out, the distinctive marks the vehicles used have to show, the documents such vehicles have to carry, as well as the requirements as to safety and hygiene, inspection, and penalties.

Point 3 (page 549) is to be reworded as follows :

3. Taxation of motor vehicles, subsequent to the last codification of 1926, has been modified in many cases in order to procure additional revenue and to simplify the bases on which taxes rest and their collection. The new legislative and administrative texts on the subject were brought together and grouped methodically in the codified texts published in the *Official Journal* in December 1934, and January 1935 (Code of taxes on business turnover and of unified taxes, and also the code of indirect taxes).

From these codified texts the situation appears to be the following :

As regards *taxes on motor vehicles*, the road tax introduced by the *decree of the 28th December 1926* was abolished by the law of the *23rd December 1933* introducing a new method of motor taxation and was replaced by a extra tax on liquid fuel (also known as « road surtax »). The many *taxes on fuels* are governed by a large number of legislative and administrative acts. The *law of the 28th February 1933* imposed a tax depending on the turnover of motor transport undertakings, certain classes of which were, however, excluded. Special fiscal rules were introduced by the law of the 31st May 1933 for the benefit of travelling shows, hawkers, etc. The *law of the 28th February 1931* quoted above introduced a tax depending on the weight and size of the vehicle. The *law of the 25th December 1934* took off the (reduced) licence tax on vehicles using producer gas or compressed-air engines.

4. The law of the *31st March 1933* and *article 27 of that of the 23rd December 1933* deal with the *subsidies* granted to public road services.

Hungary.

The following text is to be added at the end of point 3 (page 550).

Road vehicle taxation was reorganised by *decree No. 10400/34 issued by the Ministry of Finance in 1934* and published in the « Budapesti Közlöny », No. 145 of the 29th August 1935.

Italy.

The following note is to be added to point 7 (page 551).

Note. — Goods road services over fixed routes to regular timetables, the only ones considered in the *Regulations on motor vehicles not running on rails* (see point 1), occupy an insignifiant place in goods motor transport. This transport was, as a matter of fact, subject to no effective regulations and so was not under any control; nor had the users any guarantee.

A *bill of law* to regulate the *carriage of goods by motor vehicle* (Disciplinamento dei servizi di trasporti merci mediante autoveicoli) was submitted to the Chamber in December 1934 to meet this need (*).

This law broadly speaking regulates professional transport carried out either to order (servizi di noleggio), or by using vehicles standing for hire (servizi di piazza), or finally by regular line services (servizi di linea). The law also applies to the carriage of goods by individuals on their own account, such working whilst unfettered being subject to a licence for registration purposes. The reason for this measure is that such individual owners must be prevented from using their vehicles on behalf of other firms, for example on the return journey.

The wording of the two last paragraphs of point 9 (page 551) should be as follows :

9. The above mentioned regulations put into force by royal decree No. 710 of the 29th July 1919 lay down the general regulations as to safety.

Decree No. 3179 of the 2nd December 1928 completes the regulations on the subject of loading gauge, length, and weight of vehicles running on the public roads. (*Decree No. 1093 of the 29th June 1932* classifies motor cycles with light cars).

Note. — The figure 9 now marking the second paragraph of the second column of page 551 is to be deleted.

The following text is to be substituted for point 10 (pages 551 and 552) :

10. As regards taxes other than customs duties (dazii erariale) and the tax on sales (tasse di vendita) of petrol, lubricating oil, and pneumatic tyres, the royal decree of the 30th December 1923 introduced a road licence tax (tasse de circolazione) based on the power of the engine and varying with the class of vehicle and its use (private cars, taxis, omnibuses on fixed services, lorries, trailers, etc.).

The requirements of the same royal decree have been completed and in part modified by the following decrees :

Decree No. 13 of the 30th January 1933 and No. 1239 of the 26th September 1933 on the method of paying the road licence tax; *decree No. 1093 of the 29th June 1933* on the tax on motor cycles; *decree No. 1549 of the 28th November 1933* on a surtax on trailers; *decree No. 1984 of the 3rd December 1934* on certain reductions in the motor vehicles taxation; and finally the *decree of the 4th February 1935* putting into force the preceding decrees.

The second sentence of point 11 (page 552) is to be worded as follows :

This in the first place will encourage the sale of small vehicles. This was the object of decrees *No. 157 of the 25th April 1932* and *No. 4 of the 9th January 1934.*

(*) This bill was subsequently passed as *law No. 1349 of the 20th June 1935.*

Switzerland.

Point 5 (page 554) should be rewritten as follows :

5. The first step towards *co-ordination of rail and road transport* was the drafting of a *federal law regulating the transport of goods and animals in motor vehicles on the public roads* (law on the allocation of goods transport). This draft was approved by the Federal Chamber, but was rejected when submitted to a public referendum on the 5th May 1935.

The intentions of this law were made clear by the proposed orders dated the 16th April 1935, drawn up jointly by the general Management of the Federal Railways, the Swiss Association of Motor Lorry Owners (A. S. P. A.), and the Swiss Automobile Industry Chamber.

Czechoslovakia.

The following text is to be substituted for that dealing with Czechoslovakia :

1. From the 1st July 1935 the regulations other than those affecting safety applying to motor transport in Czechoslovakia are based on the new *law No. 77 of the 12th April 1935 on motor transport* (Zákon o doprave motorovymi vozidly a jich zdanèni) and ordinance No. 153 of the 4th July 1935 putting it into operation, which govern not only the system of concessions and licences but also the taxation of motor transport of all kinds (taxes on the vehicles and taxes on road transport).

The new law, whilst broadly repeating the requirements of the previously mentioned law, imposes on transport which so far had escaped any control a new form of authorisation, namely licences, and adds certain regulations to assist the railway and road transport interests in coming to terms so as to co-ordinate the two. A fiscal clause in this law was inserted to lead the owners (works, traders, etc.) of motor lorries used on their own account to agree with the railway as to the use of their vehicles.

2. As regards the control, the requirements of the ministerial ordinance No. 81 of 1910 of the former Austrian Empire and a similar ordinance No. 57000 also of 1910, for former Hungary, remain in force and form the basis of Czechoslovak practice.

These orders have been made more complete by the Czechoslovak law No. 120 of the 16th July 1931, followed by ordinance No. 107 of the 30th June 1932.

A new *law, No. 81, dealing with the circulation of road motor vehicles* (Zákon o jízde motorovymi vozidly) will come into force at a date to be determined by a decree the drafting of which is nearly completed. This law will contain the provisions of the acts quoted above.

3. The *contributions* of motor owners and motor transport firms towards the construction, reconstruction, and maintenance of the public roads were regulated by law No. 116 of the 14th July 1927, completed and modified by law No. 76 of the 7th May 1931 (Zákon o silničnion fondu). The new transport law, No. 77 of the 12th April 1935 retained these regulations.

Law No. 116 of the 4th July 1927 dealing with the funds for improving the roads allocates thereto the receipts from the road licence taxes on road motor vehicles, the import duties on pneumatic tyres, and half those on mineral oils as current revenue. Law No. 77 of the 6th May 1931 added to these receipts 70 % of the duty on mineral oil consumption.

The new law, No. 77, of the 12th April 1935, on road motor vehicles, modifies the sources of this fund to some extent.

Another new law, *No. 78 of the 12th April 1935* (Zákon, jimz se mèni nèkterá ustanoveni a spotrebni dani z minerálnich olejů) amended an earlier law, No. 77 of the 6th May 1931, on the tax on mineral oils used, by increasing this tax to compensate for the loss to the road fund caused by the alleviation of the fiscal charges, resulting from the new law on motor transport.

4. Until law No. 81 of the 26th March 1935 on the running of road motor vehicles (see point 2), comes into force, the *responsibility* of the owner of mechanical transport vehicles and those who use or drive them is governed by the *former Austrian law No. 162 of the 9th August 1908* followed by *decree No. 221 of the 28th October 1908* mitigating the provisions of the above mentioned law as regards the owners of low-speed vehicles. Another *decree, No. 156 of the 13th October 1927*, completed the provisions of law No. 162 of the 9th August 1908.

Operators of public road services were required to take out an insurance policy by the law of the 23rd December 1932, the conditions being specified in the order of the 6th February 1933. This question is also dealt with in the above mentioned new law and in law No. 77 of the 12th April 1935.

Jugoslavia.

The last two paragraphs of point 1 (page 555) are to be replaced by the following text :

As required by paragraphs 62 and 83 of the law on transport undertakings, the application of this law is the object of the *regulations on the transport of passengers and goods by road motor vehicles* (Pravilnik o prevozu putnika i tobe motornim kolima) decreed on the 16th May 1935 by the Minister of Commerce and Industry in conjunction with the Ministers of the Interior, Public Works and Communications, as well as the Minister of Social Welfare and Public Health. These regulations lay down the detailed provisions relating to the working of transport undertakings, the method of granting concessions to such firms, the insurance to be taken out, the vehicles to be used, and finally the control of such undertakings.

Note. — The law on transport firms referred to under point 1 (page 555) was published in the Official Gazette, No. 262/LXXXI of the 9th November 1931 and came into force on the 9th March 1932.

The second paragraph of point 3 (page 556) is to be completed by the following text :

According to the requirements of *paragraph 8 of the law of the 12th December 1930* (the only one remaining in force) passenger service operators are required to pay a special tax for the upkeep of the roads.

Prior to the 1st April 1935, motorbus services were subjected to a vehicle tax based on the tare weight, a tax on tickets, a tax of 10 % on the gross receipts, for abnormal road wear, and to provincial and local taxes, based partly on the weight of the vehicle and partly on the tickets sold.

However, in accordance with the financial law in force, the Government issued two ordinances, in force as from the 1st April 1935, reducing the taxation of motor vehicles. One of these ordi-

nances abolished the local taxes and the other modified the application of the tax on tickets sold in the case of motorbus services, by making a distinction according to the degree of competition with the railway.

* * *

CHAPTER I.

Classification. — Basic facts.

The object of the above enumeration of the legislative and administrative provisions relating to road motor vehicles is :

1. to give a brief account of the regulations in different countries.

2. to furnish the basis for the analyses of these regulations we propose to undertake and to make it easier to refer to the laws and orders or decrees quoted in these analyses.

We felt it would be best to follow more or less the same order when quoting these legislative measures of the different countries.

Each part begins therefore with the legislative measures more especially devoted to what we consider the *main object* in regulating motor transport. This regulation (see *preamble* p. 542 of the Bulletin, May 1935) is that which endeavours to *introduce order in the professional working of road transport* in the general interest and in that of a reasoned transport policy, and if possible to bring private goods transport by road within the framework of such a policy.

This legislation mainly applying to *public services* deals more particularly with the conditions of the concessions or authorisations required by those wishing to operate such transport. This legislation sometimes includes special provisions relating to the safe working of the vehicles employed and the responsibility of the operator to the passengers, as well as others on the special taxation of such transport. In many cases, however, these provisions are scattered amongst many acts or mixed up with those also applying to private transport.

In certain cases the special regulations applying to public services are to be found in a number of acts, each dealing with a class of service or a branch of their activities.

When necessary, we have noted after or instead of the acts in question those specially intended to effect a better *co-ordination of rail and road transport.*

Following on these special legislative measures we give :

a) the general provisions relating to *safety* (police regulations, road codes, etc.) applicable to the working of road vehicles;

b) the *general* provisions relating to the *taxation* of motor transport and the vehicles used in connection therewith;

c) the *general* provisions establishing the *responsibility* of road transport operators or of the owner of the vehicles used.

* * *

Having explained the general classification of the data available for the proposed analyses, the first task in connection therewith is to shew the classes of motor transport coming under each country's special regulations. The following chapter is devoted to this purpose.

In order to make the results clearer and more instructive, this examination must be done methodically. This means a *preliminary classification* of the information into *road transport groups*

after *defining each group* at least generally.

The first distinction is between *passenger* and *goods* vehicles. The former, it should be remembered, are used frequently to carry luggage, parcels, and mails. On the other hand in spite of its being forbidden, lorries carry passengers (to fairs, sport meetings, etc.). When later on we speak of public passenger services this remark must be remembered.

Another distinction is between *public* and *private transport*.

This distinction appears useless in the case of *passenger traffic* if we exclude motor cycles, cycles, and private motor cars which are only used by the owners for their personal requirements. One might be tempted to consider all other transport as « public ». There are, however, certain classes of passenger transport which, whilst not being really private transport, cannot be considered as public without a careful investigation. Such are transports which without being worked for third parties are not public in that they are not available to the general public. An example is given by taxis engaged by someone for the sole use of a given client or group of individuals. Then too, while passenger transport over given routes by omnibuses is definitely public, this cannot be said off hand of *tours in motor coaches organised by travel agencies or hotels*. Taxi services available to the public and operated professionally can hardly be grouped with public services such as public motor omnibus or motor coach services. Firms hiring out their vehicles are included under a separate heading as we shall see later on.

As regards *goods transport,* we must begin by saying that we have not been able to eliminate *privately-owned lorries* from our examination as we did motor cycles and private motor cars.

To begin with, the number of privately-owned motor lorries, i.e. dealing with the transport required in connection with an industrial, agricultural or commercial undertaking, and owned thereby, is several times greater than that of motor lorries used in public services.

The difference in the conditions under which motor passenger and goods vehicles can be used *alternatively* in private or public services must be taken into account. A motor vehicle to be really a private vehicle and so give its owner the service and advantages he requires of it cannot be available for general use. The opposite is the case with lorries the owner of which does not hesitate to use them on behalf of a third party or to hire them out temporarily. Then too any one can if need be hire without difficulty lorries belonging to a third party.

Public transport services are often described as being operated « professionally ». This expression should be used with care, keeping in mind the following facts, for example :

— the hiring out of motor vehicles (see below) is also done professionally; in the same way, the hotels industry in some cases implies the transport of visitors. This case also covers funerals by undertakers. To be *professional* in the sense of the regulations of many countries, the organisation of transport must be the special and exclusive business of the firm in question, in other words must be the trade of the operator.

In countries in which the motor regulations are based on the general regulations applying to professions, the professional character of road transport is indirectly defined by the provisions of

these general regulations. The characteristics of professional activity are defined for example as being continuous and not temporary, carried on independently on behalf of the owner as his means of livelihood, and not for his personal needs. Certain intermediate forms of transport operated on behalf of a third party may not have all the above characteristics; their operators consider they are not really professional carriers and so need not apply for the concession required in the case of professional transport firms. These operators, when prosecuted by the authorities, escape punishment by proving that they do not comply with all the requirements usually expected in the case of professional activity.

For example, we find associations (sometimes fictive) of a limited number of members set up with the pretended sole object of conveying their members from their homes to their work and back. The managers of these so called associations are frequently professional hauliers who are unable to obtain the necessary concession for this sort of transport owing to their failure to comply with certain conditions. The price the passengers pay is stated to be a contribution to the association to meet the working costs. As no proper control is possible, the operators of such irregular transport, in the guise of employees of the associations, make sure of a profit and of being able to use their vehicles, which they could not do legally otherwise.

Another way of evading the regulations on professional transport is to *hire* vehicles belonging to operators who either do not or cannot obtain the necessary concession. These operators usually carry out occasional transport at the request of customers with their own vehicles and drivers, pretending that the vehicle has been hired for each journey and that the driver is working for and on behalf of the customer for which the transport is being worked.

Another example is the *frequent use of private lorries* for transport for others than the owner (especially in the case of return loads). The professional character of such transport is difficult to prove if the owner of the vehicle pretends not to be paid at all or not to look for a profit, being content with a payment which covers the outgoings or a part thereof. Actually even if he receives the minimum return he is able more easily to cover his own costs and this is his indirect profit.

The above shows how desirable it is not to base the characteristic of professional transport on the notion of direct *remuneration* alone.

Professional transport properly speaking can with few exceptions be grouped with public services.

The present regulations on transport (public or professional) divide it according to some criterion into two classes and exclude one of them from the regulations, or else apply less stringent rules to one than to the other.

Thus if the criterion be *regularity* of public transport we get :

1. services over fixed routes at fixed times (regular services);

2. occasional services or to order under two different forms, that in which the vehicle stands for hire on a public place (taxicab and taxi lorries) and that in which the vehicle must be applied for at the firm's headquarters.

A further distinction is based on the criterion of the *capacity* of the vehicles

used, especially in the case of passenger traffic. Certain legislative acts only relate to transport in common of passengers frequently ignoring completely transport by vehicles with limited seating capacity (such as taxi-cabs). Normally the minimum number of seats is fixed arbitrarily and transport in common is taken to mean vehicles with more than 6 to 8 seats excluding the driver's.

Some of the regulations examined distinguish — especially in regard to passenger traffic — *permanent services* from *temporary services* (such as services organised during the summer for tourist traffic). Obviously this distinction can apply best to regular services at fixed times but not to occasional goods services which form the bulk of the road traffic.

The distinction between public services according to their *radius of action* must also be mentioned, whether :

services operated solely *within the boundaries of a town* or centre of population;

interurban services with possibly a differentiation between short-distance (local) and long-distance services.

Whilst we are still dealing with the *nature* of the transport, we must call attention to the distinction between *cartage* which covers the collection and delivery of parcels and transport by *full load* (usually interurban).

Then too the further distinction *according to the person who operates public services* must be noted.

For example, some regulations grant public services operated by *local authorities, private railways, inland navigation companies, or airways,* etc. certain advantages and so make a distinction between such services and all others.

In some countries services managed by the State, whether the *Post Office* or the *Railways*, are given *preference*.

In addition to mentionning in the next chapter the special regulations giving the two classes of transport referred to in the last two paragraphs some special treatment or certain facilities, we shall devote a special chapter to these two classes so as to bring out especially in connection with the second, the circumstances which are at the root of this differentiation, and its objects.

It should be remembered too that certain special regulations make a distinction in the case of public services (especially passenger services run over prescribed routes at booked times) between *services subsidised* by the State, provinces or local authorities, and *non-subsidised services*.

Then too the *hiring of motor vehicles* must be mentioned. The firms who hire out motor vehicles were established for this particular purpose and usually escape all motor transport regulations.

Haulage firms, moreover, sometimes hire out their own vehicles, especially during slack periods. In both cases the vehicle is hired with or without the driver. This shows how easy it is to operate transport for someone (professional) and escape the regulations on the professional transport of goods on the one hand, always stricter than those applying to private transport (even supposing the latter is subject to any regulation), and on the other the regulations on private transport if there are any.

* * *

In the following chapter we shall see not only which of the classes mentioned in this chapter come under the regulations of each country, but also the defi-

nitions of these regulations applied to any of these classes.

* * *

CHAPTER II.

Bearing of the regulations considered on the different classes of motor transport.

Preliminary note :

The legislative or administrative acts are referred to by the numbers used in the enumeration and if need be by the pages of our preceding article in the Bulletin *(May 1935) or the supplement thereto at the beginning of the present article.*

I.

We will begin by seeing which of the special regulations on *motor transport* which we quoted in the preceding Enumeration *at the head* of the section devoted to each country is solely concerned with *professional (public) transport, how such transport is distinguished from private transport, and if the latter is regulated in any way.*

1. — Germany.

The ordinance of the 6th October 1931, still in force in the case of goods transport (point 1, page 544) only concerns professional transport which it defines as that carried out for payment; private transport is explicitely excluded; no more definite distinction is made between the two kinds, however. In Germany transport carried out by industrial, agricultural or commercial undertakings in connection with their own business is considered as private goods transport (Werkverkehr). In each case it is the competent general administrative authority who decides whether any particular transport shall be considered as private or not, after consulation with the Post Office and State Railway Administration, as well as the bodies representing the interests of trade, of the motor industry, and of motor transport.

The *new law of the 4th December 1934* (point 1, p. 544) in the future only governs *public* passenger transport as defined in the first paragraph as *professional* passenger transport, without any more precise definition.

The new law on long-distance motor goods transport (Supplement, p. 132 of the present article) which will come into force on the 1st April 1936, explicitely excludes transport carried out by private individuals, without any further definition. As far as the authorisation to be obtained by motor transport operators is concerned, this law only makes such an authorisation obligatory for firms working transport outside a radius of 50 km. (31 miles) from their place of residence.

2. — Austria.

The special Austrian law of the 3rd October 1931 (point 1, page 545) on road transport over given routes, designates these as public transport for reward.

Transport worked by firms to convey their employees and workmen from their homes to their place of work and back, and within their premises, as well as the transport of their products and stores; the transport of hotel visitors, patients at sanatoriums, etc., organised by the owners; the transport of co-operative societies, and regular haulage in connection with transport worked by other transport methods, are all outside the scope of this law, as they are not considered to be public transport. Such transport, although not explicitely recognised as private, is not obliged to obtain a concession.

The above law excludes the transport undertakings coming within it from the *general* regulations on professions.

The decree of the 31st March 1931 (point 3, page 545) which subjects to a concession all *professional* goods transport by motor lorry, is not abrogated by the above mentioned law, being based on the general regulations on professions. After the above mentioned law comes into force, this decree will naturally only apply to *occasional goods transport*.

The decree of the 9th June 1933 (point 4, page 545) fixing minimum rates for interurban transport by motor lorry for payment, excludes from such obligation *private goods transport* which it defines as follows :

That transport is to be considered as « private » which consists of the carriage of goods for business purposes by a firm which is not a professional transport firm, when such transport is carried in vehicles owned by the firm or in vehicles hired by the firm at its own cost and risk, such vehicles being driven by the owner or staff of the firm.

The essential condition is in every case that the goods carried shall belong to the two categories given above.

But the *decree of the 9th June 1933* affects likewise the transport of goods in privately-owned lorries on behalf of the owner, by limiting the distance over which they can be used.

3. — Belgium.

The *special law of the 21st March 1932* (point 1, page 546), on public omnibus and motor coach services considers as *public passenger services* those which meet the following conditions :

When the seats are hired to anyone on request, wherever passengers are picked up, when payment is according to a fixed rate or by agreement, and when the service is worked between localities or places fixed by the operator, even if the time of departure is not published, or if the service does not run at the time and date announced.

Services organised by an employer for the sole use of his staff or family, and services organised for special unforeseen events, or to supplement a sudden shortage, or the temporary or accidental suspension of public transport services, *are not considered as public services*.

In the case of *goods transport in motor vehicles,* clause 1 of the bill of law on better co-ordination of rail and road put forward in March 1934, only subjects to authorisation goods transport *worked on behalf of a third party for payment*. Private transport is unaffected.

4. — France.

The *decree of the 19th April 1934* (point 1, page 547) gives in clause 7 the following definition of public road transport of passengers and goods :

All services offered to the public for *commercial* reasons are to be considered as public transport services as regards the application of the present decree.

The *decree of the 25th February 1935* (see Supplement to point 1, page 133, of this article), dealing with the *administrative regulations* in connection with the co-ordination of railway and road passenger transport, makes clear what is to be considered as *public transport* by the following enumeration of what is not :

The following are not to be considered as public transport services : the transport of passengers worked by any industrial, commercial, agricultural, or private undertaking exclusively on its own behalf, with vehicles belonging to it or hired by it, on condition that such vehicles only carry, in addition to the

driver, persons attached to the undertaking in question.

The proposed agreements between the railways and transport firms show that the definition given in clause 7 of the above decree is sufficiently clear to show what categories of *goods transport firms* are covered by the regulations. Unlike occasional passenger transport worked in taxi-lorries which are excluded from the effects of the decree of the 19th April 1934, occasional goods transport worked commercially by their operators will be covered by the new regulations, particularly as they form the bulk of public goods transport.

The *decree of the 13th July 1935* (see Supplement to point 1, page 134 of the present article), dealing with the coordination of goods transport by rail and road actually only covers *public* transport and explicitely excludes *private* transport. The latter is defined and all other transport is declared to be public, certain categories which might appear doubtful being specified as public. In addition the decree makes a distinction between the different kinds of public transport (cartage, general regular services, special services for the transport of livestock, liquids in tanks, removals, transport on request, etc.).

5. — Hungary.

The *special law XVI/1930* (point 1, page 549) only deals with *public motor transport firms*. According to this law, *public* transport firms are those which carry passengers and goods for payment, whether regularly or occasionally, their vehicles being at the disposal of the public.

6. — Italy.

According to clause 30 of *decree No. 710 of the 29th July 1909* (point 1, page 550) modified by decree *No. 705 of the 7th May 1922*, a concession has to be obtained by all road services of no matter what kind or length, *over booked routes;* the only services excluded are those worked by taxis, which have to make runs whenever ordered. Actually these regulations only apply to public *passenger* transport.

In the case of *goods transport the bill of law drafted in December 1934* and passed as law *No. 1349 of the 20th June 1935* (see Supplement, point 7, page 135) is intended to regulate *all* goods transport worked for third parties to order or in hired vehicles i.e. occasional transport. The bill of law also covers goods transport services over *regular routes* and so to some extent encroaches upon the object of the previous decree.

While traffic worked in *privately-owned lorries* is left unaffected, the above bill of law lays down in clause 1 that the use of private motor vehicles (including trailers) for carrying goods is only under the obligation to take out a licence, which is in the nature of a preventive formality, and to carrying a distinctive mark.

7. — Poland.

The *special law of the 14th March 1932* (point 1, page 552) dealing with transport worked *for payment* as its title indicates, does not define such transport. The definition is given however in the following paragraph of the *order* putting it into force.

All passenger and goods transport is considered as being *for payment* which is worked by the organisers for profit no matter what the kind and form of such profit.

The *negative* definition referring on the contrary to *private* goods transport, given in the special law, covers the goods

transport of industrial, commercial, agricultural, or forestry undertakings, worked by such undertakings exclusively in connection with their own business, in their own vehicles. This definition was enlarged in scope by the order putting the law into force.

8. — Rumania.

The *special law as drawn up on the 15th October 1932* (point 1, page 553) only deals with public passenger and goods services, without defining such transport either negatively or positively.

It must be remembered however that clause 1 of this law recognises as a State monopoly the organisation of such services and that clauses 2 and 3 make provision, on the one hand, for the State to work this monopoly, and on the other, for granting the right to operate certain services to private firms. Taxis worked within local areas are the only vehicles outside the monopoly.

Private transport is not covered by the special Rumanian legislation.

9. — Switzerland.

As far as motor *passenger* transport is concerned, the *law of the 2nd October 1924* on postal services gives the Post Office Administration the exclusive right to work *public* transport over regular routes. This right does not apply to regular passenger transport, when not carried out professionally, nor when required by the business of an undertaking not concerned in the transport industry.

According to clause 3 of the above law: « Concessions can be granted for the regular transport of *passengers to undertakings whose business this is* », but with the exception of one single provision on the responsibility of such firms, the law does not deal any further with this category of transport, the importance of which would appear to be little in comparison with the services organised by the Post Office Administration itself.

The *bill of law on the distribution of goods transport* (see Supplement to point 5, page 136) defines in clause 1 as *professional transport* the regular or occasional transport of goods worked for payment, and on the other hand as *private transport* (clause 2) transport by the owner of the vehicle or his employees on is own behalf. The latter transport is unrestricted (first paragraph of clause 2), and in addition the undertakings or persons working such private transport are also allowed to carry goods belonging to a third party in their vehicles for payment, for distances up to 10 km. (6.2 miles) without any restriction, and for greater distances only where the transport is not covered by railway or by professional goods transport road services with fixed itineraries as laid down by this law.

The *draft order for putting it into force* (see Supplement point 5, page 136) defines the idea of remuneration in the following way :

In the case of transport « worked against payment » the remuneration covers all immediate payments or promises of payment from the customer to the owner of the vehicle, whether in money, in kind, or for services rendered, the giving up of some right, or the granting of some privilege.

The same draft gives the following precise definition of private transport :

A firm's « own vehicles » are those completely owned by it or bought on a hire-purchase system, subject to the supplier's interest.

Hired vehicles can also be counted as privately owned when used for a short time in the place of one of the

firm's own vehicles temporarily out of service.

The legal requirement that the transport be worked for the business of the undertaking is fulfilled when it is a question of goods bought by the firm to be consumed, re-manufactured, or resold by it, or of its own manufactures. The object of the transport must be to bring the goods to the premises of the firm, transport them therein, or carry them to the buyer.

The legal requirement that the transport be worked by « the firm's own staff » is fulfilled when the vehicle is driven by the owner himself, or by an employee who apart from this is not a professional driver nor employed by other transport firms. Is reserved the employment for short periods of auxiliary staff, for example if the regular employees be ill or on military service.

Undertakings or persons who, while working their own transport, also work on behalf of a third party for payment for distances exceeding 10 km. (6.2 miles) have to advise the authorities granting concessions.

10. — Czechoslovakia.

The *special law of the 12th April 1935* (see Supplement point 1, page 136) based on the existing general *regulations* on professions, deals in the first place with *professional transport* worked on a concession (§ 1/1). In addition, Chapter IV of the same law contains the regulations on *licences*, less strict than in the case of concessions, for certain classes of goods transport and certain classes of passenger transport in common, when not worked professionally. It excludes (§ 34) from the system of concessions and licences :

private individuals conveying their own staff in their own vehicles;

the transport of goods manufactured or exchanged in connection with the business of an undertaking, carried between the works and the premises of its customers or between the business and its branches,

the transport of articles used by the firm and in connection with the manufacture of its products;

cartage services between the producer or consignee and the loading station or dock.

All such transport must be worked in vehicles owned by the firm and driven by the owner or his employees.

The proprietor of the business in the event of unusually heavy demands or other exceptional reason, as a temporary measure, can use other vehicles hired with their drivers if required.

No concession or licence is required by owners of agricultural, industrial, etc... tractors, if it is officially certified that such vehicles, when suitably loaded, cannot exceed a speed of 12 km. (7.5 miles) an hour on the best roads.

The system of licences was introduced to prevent the numerous attempts to get round the regulations on concessions thereby prejudicing professional transport; such attempts were often successful as it was very difficult to prove their professional character.

In this connection, we would refer to Chapter I, page 142 and following, of the present article. Having defined (see above) the classes of transport excluded from the systems of concessions or licences, the object of this legislation is to make those who operate transport services on behalf of third parties reveal themselves and submit to one or other of these two systems.

The law which regulates in full detail

the whole *taxation* of vehicles and motor transport, likewise applies to privately-owned motor vehicles, but without any differentiation in respect of their use. This does not apply to *privately-owned motor lorries* which, after the 1st January 1937, will have to pay a greatly *increased road tax* if their owners have not come to any agreement with the railway as regards their utilisation. Chapter IX of this law regulates the way the respective agreements shall be made, the details of which will be regulated by a governmental order to be passed in due course.

11. — Jugoslavia.

The *general companies law* (see the second paragraph of point 1, page 555) only applies to regular and seasonal transport worked *professionally*. The *decree of the 10th May 1934* (point 2, page 556) regulates, within the limits of this law, the occasional transport of goods, which from the point of view of authorisations, is treated as regular or seasonal transport. A more detailed definition of professional transport is not given by the existing legislation which does not affect private transport in any way.

The *regulations of the 16th May 1935* (see Supplement, point 1, page 137) deals in the first place with professional passenger transport and more particularly with regular services. In the case of goods transport, it only applies to professional transport (regular or occasional) which is negatively defined in clause 8.

* * *

The data given above is summarised in the following table.

Country :	Kind of transport.	The special legislation in force or proposed, of the country, relative to passenger (P) or goods (G) transport.			
		Regulates public transport.	Regulates private transport.	Defines public transport as :	Does or does not give a detailed definition of public transport.
Germany . .	P	Yes.	...	Worked professionally.	...
	G(1)	Yes.	...	Worked for reward.	Gives a negative definition (by enumerating private transport).
	(2)	Yes.	...	Worked on behalf of a third party.	...
Austria . .	P	Yes.	...	Worked professionally for reward.	Gives a negative definition (by enumerating private transport).
	G	Yes.	Partly.	Do.	Do.
Belgium . .	P	Yes.	...	...	Do.
	G	Yes.	...	Worked on behalf of a third party for reward.	...

(1) Legislation in force.
(2) Regulations which will come into force on the 1st April 1936.

Country :	Kind of transport.	The special legislation in force or proposed, of the country, relative to passenger (P) or goods (G) transport: Regulates public transport.	Regulates private transport.	Defines public transport as :	Does or does not give a detailed definition of public transport.
France	P G	Yes.	...	Services offered to the public for commercial purposes.	Gives a negative definition.
Hungary	P G	Yes.	...	Worked for reward.	...
Italy	P	Yes.	...	Services over fixed routes.	...
	G	Yes.	Partly.	Worked on behalf of a third party.	Gives a precise idea by defining private transport requiring a licence.
Poland	P G	Yes.	...	Worked for reward.	Gives a negative definition.
Rumania	P G	Yes.	...	Public haulage services.	...
Switzerland	P	Yes.	...	Firms carrying out regular passenger transport professionally.	...
	G	Yes.	...	Worked professionally for reward.	Gives a negative definition.
Czechoslovakia	P	Yes.	Partly (3).	Worked professionally.	Gives a negative definition on the one hand by introducing licences, and on the other by specifying the transport (private) which evades licences or concessions.
	G	Yes.	Partly (4).	Do.	
NOTE. Transport of a character intermediate between public transport (professional) and entirely private transport has to take out a special licence.					
Jugoslavia	P	Yes.	...	Worked professionally.	...
	G	Yes.	...		Gives a negative definition.

(3) As regards taxation.

(4) As regards taxation and by imposing surtaxes upon owners who have not come to an agreement with the railway about the utilisation of their vehicles

The above table shows such slight differences concerning the more precise definition of what we have called « public » transport, that we might be tempted to endeavour to give a general definition of such transport, taking them into account.

We think, however, that it would really be valueless. All the difficulty the legislatures in the different countries find in endeavouring to define motor transport in order to regulate it, seems to be due to the fact that too much attention has been paid to the idea of « transport » and too little to the idea of « service ». It seems to us that it would be more logical to use the term « service » as this already explains quite clearly the kind of activity concerned. If only such a definition were used, it would hardly be necessary to characterise such an activity as « professional » or exercised commercially for profit (reward). It would be sufficient, in our opinion, to add to the word « service » the word « public » (service public d'autobus, d'autocars, de voitures de place, d'autocamions, etc.), to cover the whole of the cases the legislation in question is intended to include.

In languages other than French with no proper equivalent of the word « service », a composite term would have to be selected, for example one expressing the idea « transport undertaking » and be used in the text of the regulations intended to regulate this kind of undertaking only.

[621. 131.1 & 621. 131.2]

The horse-power of locomotives. Its calculation and measurement,

by E. L. DIAMOND, B. Sc. (Eng.), A. M. Inst. C.E., A. M. Inst., Mech. E

(The Railway Gazette).

Although it is the oldest and the simplest of the agents devised for hauling loads in wheeled vehicles, the steam locomotive remains in some respects the least understood of machines. Its capabilities, like those of electric and internal combustion units, are related in some way to the dimensions of its various parts and to the conditions under which it is set to work, but the necessary relationships involve a host of factors, and to this day the formulæ relating to the steam locomotive are either very imperfect or very limited in application. The result is that while railway services to be worked electrically or with internal combustion engines can be planned, and are planned, with exactitude and so as to derive the greatest advantage from the means employed, those to be worked by steam locomotives are still organised almost anyhow. To determine the ideal timings for steam trains and to lay down the most suitable programme for steam locomotive control over a given route it is necessary, in the continued absence of any reliable formula for the steam locomotive, to undertake first of all extensive experiments on the track on the type of locomotive to be used. Work of this kind has actually been carried out on the Continent, and there the systematic planning of steam operated services is consequently within the realms of practical possibility. Running trains to within a few seconds of a given timetable is practised as well in this country as elsewhere, but in many instances the timetable itself fails to give the locomotive a chance of showing its strong points. Time keeping is assured by allowing steam trains three and four times the interval commonly allowed to electric trains at stations, and by granting a degree of latitude to the driver in the handling of his engine which must be accounted little short of barbarous when due consideration is given to the effect of the personal element on maintenance and on fuel and water consumption.

In old fashioned designing a semblance of propriety was given to rather half-hearted incursions into the realms of theory by the introduction of what was called euphoniously enough the safety factor. Today a discrepancy between theory and practice necessitating the multiplication of a theoretical figure by five or six would call for and receive critical examination. Competition for business is far too keen to permit the addition of pounds of metal to any part where ounces would do. Train operation no less than manufacturing calls for a precise understanding of the factors affecting the end to be attained. A railway is a factory producing ton-miles and the output is sufficiently vast for it to be a matter of some concern if the cost of transport is a fraction of a farthing per ton-mile higher than it need be, due consideration being given to public demands in the way of speed and stopping places. There is nearly always a best way of doing things and latitude of any kind is to be deprecated where the proper course of action has been made manifest.

How far the performance of steam

locomotives is from being the cut and dried result of official planning is made evident by the enormous amount of train timing and train watching that goes on where steam is the motive power. In our contemporary, *The Railway Magazine*, locomotive form is discussed as if locomotives were indeed living and temperamental creatures like race horses, instead of mere machines. The electric train which is run to a far more rigid programme, being far better understood, gains little or no attention from outsiders. Further evidence of the scanty understanding of the steam locomotive is afforded by the regularity with which even railway officials are surprised by exceptional runs. A train is late, or is run with a different type of engine, or with some change in the load, and runs are achieved which show characteristics of the engine never before revealed, and therefore never suspected. What the prevailing ignorance entails in the way of wasted opportunities and wasted materials no one can say, but there can be little doubt that tests carried out with the object of determining precisely and completely the characteristics of locomotive engines up to the limit of their capacity could be made to pay for themselves again and again by the rational utilisation of their results. In this issue we publish an article dealing with the measurement of locomotive power and with the possibility of estimating it from design particulars. The problem has engaged the attention of many engineers and it is the purpose of the article hereafter to collect results which have hitherto been available only in separate publications and in several different languages, and to examine them critically. In the final chapters the most recent researches will be described and some indication will be given of the way in which the present somewhat unsatisfactory state of affairs could be remedied.

(Editorial, *The Railway Gazette.*)

I. — INTRODUCTION.

Purpose of article. — The measurement of the indicated or drawbar horsepower of a locomotive at any particular point during a journey is naturally a fairly simple matter if the engine is fitted with the necessary indicating gear or a dynamometer car is attached behind the locomotive tender. What is infinitely more difficult is to establish a rationale by which the results so obtained may be related to the dimensions and design of the locomotive and the nature of the resistances it is overcoming.

The advantages of such a rationale are twofold. First, it facilitates the comparison of existing locomotives and the design of new locomotives; secondly, it permits of the exact calculation of train schedules so as to use the locomotives to the best advantage. No satisfactory rationale of this kind has yet been evolved, hence the inconclusiveness of many problems of locomotive design, and the inconsistencies of steam-train schedules.

The purely theoretical approach to the problem has never been pursued very far. The German engineers Frank and Strahl made tentative attempts in this direction; Frank's attempt was pure guesswork, while Strahl's formula for mean effective pressure is so involved, despite its wholesale assumptions, as to discourage further work in this direction.

Two other methods of approach, which may be called respectively the empirical and the experimental, have been tried from almost the earliest days of locomotives. By the empirical is meant the establishment of a formula, graph, or table of figures on the basis of available test data, which shall then be universally applicable to all locomotives, without further testing. By the experimental is meant the establishment of a criterion to which the individual testing of each locomotive type may be carried out, and by which the results so obtained may be truly compared. The empirical me-

thod, first developed in Germany, has in recent years become American practice. The experimental method, first systematically developed in France and Russia, is still essentially the Continental method.

Daniel Clark, an Englishman, was the pioneer in the systematic study of locomotive performance; his work stood in his own day far in advance of that of any of his contemporaries, and can still be read with profit. Since then, apart from miscellaneous testing and one or two critical examinations of American test-plant data by Professor Dalby and others, English railway engineers have shown no great interest in the subject; not only has no important contribution been made to it in this country, but no adequate account of the work that has been done abroad has been published here. It is hoped that the present article will remedy the latter deficiency, and that by the critical presentation on a comparative basis of the various methods of calculation and testing evolved, the whole subject may be placed in a clearer light than hitherto. So many variable factors are involved in locomotive performance that it is not surprising that much confusion exists (1).

This subject is of greater importance today on account of the current developments of railway traction in the direction of greater speed (which means that locomotives must be operated at nearer their maximum power), and in connection with the introduction of alternative forms of locomotion, for which the power can be calculated with comparative ease and exactitude.

Closely allied with the question of the power of the locomotive itself is the subject of train resistance, without which the calculation of speed-time curves and train schedules is impossible. This aspect of the subject, however, is not considered in this article, which is concerned solely with the locomotive itself. It has been more thoroughly treated in technical literature, and at the present time is the subject of extensive research, especialy in connection with the reduction of air resistance by streamlining.

Nature of the problem. — It is a comparatively easy matter to calculate with a fair degree of accuracy the horse-power which a reciprocating steam engine will give at a speed sufficiently low to avoid considerable throttling of the steam and at a fixed exhaust pressure. When such an engine, as in the case of a locomotive, attains speeds exceeding 300 r.p.m., at which considerable attenuation of the indicator diagram takes place due to the restricted passages through which the steam must pass into and out of the cylinder, it becomes much more difficult, since not only are the steam passages of complex form, but the action of the valve still further complicates the throttling effect. If all cylinders and valve gears were of standard design it would be possible to evolve empirical formulæ or factors by which to calculate the horse-power under any given conditions.

But actually cylinders and valve gears differ very greatly. Moreover the locomotive does not exhaust its steam to a condenser at a constant vacuum, but to the atmosphere through the restricted orifice of the blast pipe. Since the function of the blast pipe is connected with the boiler and not with the engine, and since its effects is dependent among other things on the action of the valve gear during exhaust, the back pressure in the locomotive cylinder will vary considerably, not only as between different locomotives, but also at different speeds and different cut-offs in one and the same engine.

(1) For a typical example of the prevalent confusion see the discussion on T. A. F. Stone's paper on « Electric Locomotives » before the Institution of Mechanical Engineers, *Proc. I. Mech. E., 1926*, p. 1001.

Finally, since the locomotive must carry its own boiler, it has necessarily a restricted supply of steam, and this may be the deciding factor as to the maximum horse-power which the locomotive is capable of exerting at high speeds. The evaporative capacity of the boiler will depend not only on its dimensions and design, but also on the quality of the fuel supplied.

The electrical engineer is able to calculate exactly the horse-power which the motors of an electric train will exert throughout their range of speed, and he is accustomed, as a consequence, to fixing the schedules of such a train with absolute precision. From the considerations just outlined it is not difficult to understand the much more complex character of the problem which the steam locomotive engineer has to face.

II. — EARLY FORMULÆ AND INVESTIGATIONS.

Work of D. K. Clarck (1852). — D. K. Clark appears to have been the first to have recognised the influence of speed on locomotive power, though he confined himself to a quantitative estimate of the mean effective pressure in terms of the cut-off. In his remarkable paper on « Expansive Working of Steam in Locomotives » (2) he gave the following approximate rule :

$$m.e.p. = (13.5 \sqrt{A} - 28) \text{ per cent.}$$

of the boiler pressure where A is the percentage cut-off. It was intended to apply for boiler pressures from 60 to 100 or even 150 lb. per sq. inch. He pointed out that this rule gave results rather too small for lower speeds and rather too great for higher speeds, thus showing his recognition of the phenomenon of indicator diagram attenuation at speed. He estimated that for speeds amounting to 55 or 60 m.p.h. the loss by imperfect exhaust caused a large increase of steam consumption per horse-power per hour, amounting to 12 to 33 per cent., according to the amount of admission.

Clark also estimated the steam consumption per indicated horse-power hour as

$$0.22A + 14 \text{ lb } (3).$$

Hence, allowing for an evaporation of 9 lb. of water per pound of coke, the rate of fuel consumption for a given tractive effort at a given speed could be ascertained. Since he gave also values of 100 lb. of coke per square foot of grate per hour and 80 sq. ft. of heating surface per square foot of grate, he established a complete empirical relationship between power and size of boiler.

Early German ratios. — Professor Nordmann of the German State Railways has several times published historical summaries of the work of German engineers on this subject. The earliest of the German attempts to evaluate locomotive power referred to by Professor Nordmann (4) is that of the theoretician Redtenbacher, who about the same time that Clark in England was publishing the results of his experience, proposed in his « Gesetzen des Lokomotiv-Baues » (1855) an expression based on the weight, in working order, of the locomotive. Such a relationship is, of course, crude in the extreme and helps to show how far in advance Clark's work was. In 1875 other German engineers published certain average ratios between the power and heating surface for various generic types of locomotives. These writers recognised that such ratios varied considerably between individual locomotive designs, but the variability of the ratio for one and the same locomotive at different speeds remained uninvestigated.

(2) *Proc. I. Mech. E.*, 1852, pp. 60, 109.

(3) *Railway Machinery*, p. 116.

(4) *Glasers Annalen*, 1911, vol. 69, p. 237.

Frank's formula (1887). — Professor Frank in 1887 expressed this same ratio as a function of the speed V in the formula

$$N/H = \alpha + \beta \sqrt{V}$$

where N is the horse-power, H the heating surface, and α and β are constants. This gives a power curve which increases with speed at a decreasing rate. The lower part of the curve lies above the limit imposed by adhesion, and is replaced by a straight line representing the product of the speed, the weight on the driving wheels, and the adhesion factor (fig. 1). The constants α and β had different values for passenger and goods locomotives.

The ratios and constants given by these early German workers were, of course, based on road test observations, Professor Frank, for instance, calculating his constants from the results of numerous observations on the then prevalent classes of passenger and goods locomotives of the former Prussian State Railways. But for a better understanding of the conditions governing power output especially at high speeds, a closer independent study of the nature of the steam action in the cylinders and of the evaporative performance of the boiler was essential.

Early work with the indicator diagram. — The use of the indicator for locomotive testing gradually extended during the following thirty years. In 1877-79, for instance, John E. Martin published a series of reports to a committee of the American Railway Master Mechanics Association in which the steam action in the cylinders was closely studied, particularly from the point of view of the practical effect of alterations to the valve gear and blast pipe. In many respects these experiments were remarkably advanced for their day, but whilst the general influence of speed on the results obtained, particularly those relating to back pressure, was frequently noted, Martin was more interested in obtaining positive results from his alterations than in reducing to scientific order the fundamental variables underlying steam action.

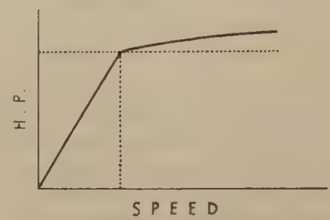

Fig. 1. — Horse-power curve. (Frank).

This failure to appreciate the immense importance of establishing locomotive phenomena quantitatively on a speed basis not only prevented for nearly half a century a closer understanding of the conditions governing the power output of a locomotive, but also is the underlying reason for the inability of locomotive engineers to settle for so long, despite endless tests, such questions as the value of steam jacketing and compounding.

The work of Desdouits with the dynamic pendulum. — The greater importance therefore attaches to the work of Desdouits who in 1890 published [5] a series of curves showing the variation with speed of tractive force at the rims of the driving wheels for different cut-offs. For this purpose he did not use indicator diagrams but a form of accelerometer or dynamic pendulum, to which extended reference will be made later [6] in connection with the Belgian method of testing. The tractive force measured by Desdouits is less than the indicated tractive force by an amount equal

[5] *Revue Générale des chemins de fer*, 1890, vol. 13, part 1, p. 271.
[6] See Chapter IV.

to the internal resistance of the mechanism of the locomotive. Some of Desdouits' curves have been modified to show horse-power instead of tractive force so as to make them comparable with the other curves of power illustratins this survey and are given in this form in fig. 2. The particular locomotive type

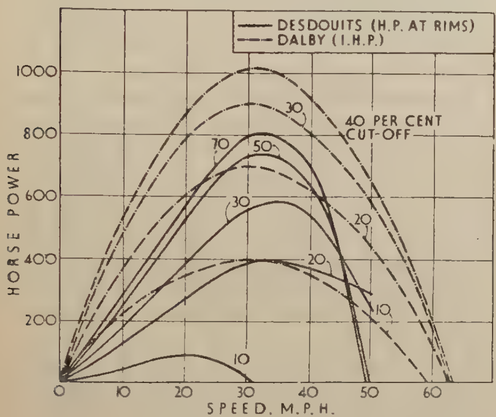

Fig. 2. — Horse-power curves (Desdouits and Dalby).

tested is of course long since obsolescent. It will be observed that these curves show a maximum, beyond which the power falls of very rapidly. Desdouits attributed this falling off to the aggravation of the effect of compression at short cut-offs and to the increase of back pressure at long cut-offs, a cut-off of 20 per cent. giving the most favourable balance between the two opposing causes of the loss of work. Desdouits' observations are of particular interest as it has so often been assumed that the boiler is the only limiting factor to the power which a locomotive can develop. Desdouits may have found that the boilers of some of the early locomotive types he tested were able to supply as much steam as the engines were capable of using under any conditions of cut-off and speed. In this country to-day there are many old types of locomotives with valve gears of the short travel type, which will, with good coal and the boiler in a clean condition, run in full gear with full regulator opening at any speed attainable, without draining the boiler. Such a state of affairs, of course, is not necessarily a meritorious one.

Desdouits made no attempt to propound a general law for the predetermination of the power-speed curve. His idea was that such a curve should be determined for each new locomotive type either by means of a series of indicator diagrams or by use of the dynamic pendulum, and in this also he was a precursor of the modern Continental attitude. The importance of his work in connection with scientific methods of locomotive testing is such that further reference must be made to is when dealing with the development of experimental technique, but it should be mentioned here that at the same time that he was studying the effect of speed on the horsepower of a locomotive he was also measuring the rolling resistance of locomotives at various speeds. He used the inertia method proposed by Frank in 1886 for the measurement of train resistance, both with the coupling and connecting rods removed so as to determine the resistance of the locomotive purely as a vehicle, and with the machinery in motion so as to determine the total resistance. The results of his experiments were published in the same article to which reference has already been made, so that, taken in conjunction with the curves of horse-power, his data afforded means for a complete study of the effect of speed on the horse-power at the rims of the driving wheels, and at the drawbar. But, as in the case of horse-power, so also for resistances he preferred the purely experimental method and gave no universally applicable formulæ such as were later evolved.

Goss's formulæ. — In September of the year after Desdouits published his paper,

the first locomotive to be tested by Professor W. F. M. Goss arrived at Purdue University. Ten years previously Alexandre Borodin had established the first stationary locomotive testing plant at Kieff in Russia, but it was of a temporary character, and suffered the serious limitation that it was not possible to absorb more than about 90 H.P. (7). Goss's plant was at first also limited to low power outputs, but with increasing experience the difficulties were overcome. A disastrous fire in 1894 completely destroyed the engineering laboratory at Purdue, but afforded an opportunity for the incorporation of this experience in a new plant, and the scientific study of the performance of the locomotive *Schenectady No. 1* and its successor, *Schenectady No. 2,* continued without interruption during the following years. The significance of this work is that, for the first time, the performance of a locomotive was studied exhaustively for the purpose of acquiring scientific knowledge of its performance in all its aspects. The phenomenon of indicator diagram attenuation at speed, the evaporative performance of the boiler, and the losses in friction, were all brought to light in their quantitative relation to each other and to the performance of the engine as a whole.

In 1901, Professor Goss published a paper (8) dealing with the power of locomotives, in which, as a result of the tests at Purdue University, he gave the formula

I.H.P. = 0.43 × heating surface (sq. ft.)

which was intended to apply only to simple engines using saturated steam. He arrived at this result by concluding that any locomotive should be able to evaporate 12 lb. of water per sq. ft. of heating surface, and that when working at full power, under the varying conditions of speed and cut-off at which that power may be developed, it requires approximately 27 lb. of steam per indicated horse-power per hour. Thus, the formula was not intended merely to represent a maximum attainable at the most favourable speed, but was regarded as a constant value, which, at the appropriate cut-off, could be obtained over a wide range of speed.

From the Purdue tests Professor Goss also estimated the internal machine resistance of a locomotive to be equivalent to a constant mean effective pressure of 3.8 lb. at all speeds. The rolling resistance of engine and tender he assumed to be not much different from that of an equal weight of train following the tender, and to be given approximately by

$$W = 2 + \frac{1}{6} V$$

where W is the rolling resistance per ton weight and V is the speed in miles per hour. The head air resistance of the locomotive, based on wind tunnel experiments made some years previously, he gave by the following formula :

$$W' = 0.11 V^2$$

In figure 3 a curve of horse-power at the rim of the driving wheels based on Goss's formulæ is shown in comparison with curves derived from the early formulæ. It will be observed that it contradicts in essential respects the conclusions of Frank. How such apparently irreconcilable formulæ could be put forward will become evident later, when the complicated conditions governing the problem are made clearer. For the present, however, it should be stated that Frank was not entirely in the wrong. Goss's assumptions of a constant rate of evaporation and a constant specific steam consumption both tend to give ex-

(7) *Proc. I. Mech. E.*, 1886, p. 298.

(8) *Bull. Int. Railway Congress*, June 1902, p. 482.

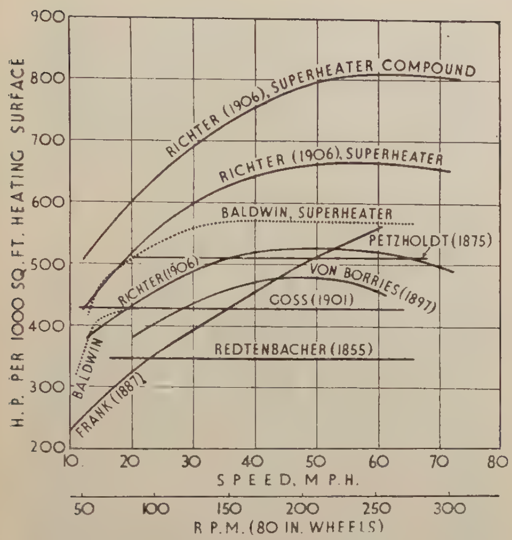

Fig. 3. — Early horse-power curves.

cessive values for power output in the lower range of speed above the adhesion limit, especially as he assumed that a tractive effort of up to one-fourth of the adhesion weight could be obtained. In the following year. E. C. Schmidt published data (9) showing that Goss's formula gave values for drawbar pull which were from 20 to 50 per cent. higher than those obtained from dynamometer tests in road service at speeds below 30 m.p.h.

Tables of von Borries. — Meanwhile, in 1897, von Borries first published his tables and curves of horse-power for specific locomotives. These were based on road performances for which the horse-power was calculated by D. K. Clark's train resistance formula. Like Frank's formula, von Borries' figures gave the ratio of drawbar horse-power to the heating surface, and like his formula also, as first published they gave values which increased continually with the speed. von Borries, however, realised that Clark's train resistance formula gave values which were too high at the higher speeds, and that actually the horse-power curve reached a maximum, after which it declined at high speeds. He may therefore be regarded as the first to perceive the true relationship between the horse-power and speed of the locomotive. It is also interesting to note that in his original tables he found it necessary to give a special column of figures for goods locomotives with a relatively small grate area, thus, as Nordmann pointed out (10) showing his recognition of the fact that the grate is the primary source of energy. von Borries' figures were revised from time to time and accepted for many years in Germany as standard; the curve in figure 3 is plotted from the figures given in the 1912 edition of his book « Das Eisenbahnmaschinenwesen der Gegenwart » as quoted by Lipetz (11).

Besides recognising the somewhat arbitrary nature of the heating surface basis for horse-power ratios, as already mentioned, von Borries also drew attention to the importance of the relationship between the heating surface and the size of cylinder and postulated that the latter should be such that the steam was expanded most economically at the speed at which the heating surface generated the greatest possible quantity of steam. How this speed was to be determined was, however, another matter. Moreover, von Borries was by no means explicit regarding the effect of the machine friction of the engine, though his figures were generally regarded as applying to the power at the rim of the driving wheels. It should be remembered that whilst both Frank's and von Borries' values depended on an out-of-date formula for train resistance, and to that extent were inaccurate, they could give results sufficiently accurate for the ap-

(9) *Bull. Int. Railway Congress*, August 1902, p. 652.

(10) *Glasers Annalen*, 1911, vol. 69, p. 240.

(11) *Trans A.S.M.E.*, 1933, vol. 55, RR-55-2.

proximate calculation of running times provided the train resistance was also estimated in this case by the same formula.

Dalby's study of the mean effective pressure. — In 1905, Professor W. E. Dalby made the first important contribution ([12]) in this country to the scientific study of locomotive performance since D. K. Clark, half a century before. Professor Dalby based his study primarily on Dr. Goss's test data from the locomotive *Schenectady,* but whereas Dr. Goss had himself examined the figures on the basis of hypothetical maximum output, irrespective of cut-off, but for an assumed constant rate of evaporation, Professor Dalby plotted the mean effective pressures at constant cut-off on a basis of piston speed, and found they lay on a straight line represented by the equation

$$p = c - bv$$

where p is the mean effective pressure, v is the piston speed, and c and b are constants for the particular engine and cut-off. This gives a parabolic curve for indicated horse-power (fig. 2) and the maximum indicated horse-power can be shown to be

$$\text{I.H.P. } n = \frac{c^2\, a}{132\ 000 b}$$

where a is the area of the pistons in square inches. Professor Dalby checked his approximation against some independent results obtained on a testing plant belonging to the Chicago & North Western Railroad, and found good agreement between the limits of 400 and 1 200 ft. per min. piston speed. Moreover, he found that the constant c, which is equal to the hypothetical mean effective pressure at zero piston speed, when no wire-drawing of the steam takes place, coincided quite closely with the theoretical mean effective pressure for the corresponding cut-off. The complete horse-power curve for that cut-off could therefore be derived if only one indicator diagram taken at a piston speed of about 800 ft. per min. were available.

Now it will be observed that while Professor Dalby's horse-power curves are equivalent to Desdouits' in their manner of derivation, except that Desdouits' are less by the power absorbed in internal machine friction, Desdouits was content to plot his actual observations, whereas Professor Dalby sought to establish a generalised rule and obtained a simple parabolic curve. Although he did not expressly comment on the point, he also extrapolated his curves to zero mean pressure at high speed, and hence indicated a limit to engine performance independent of the boiler. The piston speed at which this limit was reached was approximately the same at all cut-offs and was about 1 400 ft. per min. for a locomotive with 5 ft. 3 in. driving wheels, equivalent to 60 1/2 m.p.h. This is, as a matter of fact, considerably below the speed which such a locomotive could attain, so that not much importance can be attached to the high-speed portions of these curves.

Von Richter's formula (1906). — A new attempt to establish a formula for horse-power was made in 1906 by M. von Richter, an Austrian. In a paper before the Verein deutscher Ingenieure ([13]) discussing some new German locomotives, von Richter referred at some length to the performances of the de Glehn compounds of the Northern Railway of France, and commented very unfavourably on the relatively low speeds of the best German trains of that day, despite heavy supplementary fares, light loads, and in many cases easy grading. Like

([12]) *Proc. Inst. C. E.*, 1905, vol. 164, p. 329.

([13]) *Z. V. D. I.*, 1906, p. 554.

our own Great Western Railway, the Prussian State Railways acquired several de Glehn compounds, modelled on the Nord type, and von Richter referred to the French formula then current for calculating an average value of the horse-power, namely,

$$\text{I.H.P} = 20\sqrt{G.\,p\left(H_f + \frac{H_t}{3}\right)}$$

This formula, he remarked, did at any rate relate the horse-power to the effective dimensions of the locomotive, namely, G the grate area (square metres), p the boiler pressure (atmospheres), H_f the firebox heating surface (square metres) and H_t the firetube heating surface (square metres), and was also logical in that it gave a much higher value to the firebox than to the tube heating surface. But, of course, it gave no indication of the power to be expected at different speeds. In the case of the particular locomotive considered it gave a value of 970 H.P. In actual performance the greatest horse-power reached was about 1 450, but usually the power did not exceed 1 000 H.P., nor even 800 H.P. Von Richter then referred to Frank's formula and its ever-increasing value, and suggested that the proverb *Es ist dafür gesorgt, dass die Bäume nicht in den Himmel wachsen* is true also in the realm of locomotive performance. He therefore proposed instead the formula.

$$\frac{N}{H} = 0.1\left(a - \frac{n}{b}\right)\sqrt{n}$$

where N and H are horse-power at the rim of the driving wheels and the total heating surface respectively, as in Frank's formula, a and b are constants, and n is the speed in revolutions per minute. He admitted that this formula did not discriminate between the firebox and tubular heating surface, but considered that for values of the ratio H_t/H_f from 8 to 13, it is not seriously affected by this. In two important respects the formula represents an advance : first, it gives a maximum, at a value.

$$n' = \frac{ab}{3}$$

below and above which the power falls off, and in the second place it is based on the speed of revolution of the driving wheels and is thus independent of their diameter. Von Richter gave values of the constants a and b for various types of locomotives, including locomotives with superheaters, and some of his curves are reproduced in figure 3. It is remarkable that he assigned such a relatively high power to the superheater compound locomotive. Nordmann subsequently pointed out [14] that such an increase over the values for a superheater simple locomotive was excessive. His formula gives, however, exaggerated results for all types of locomotives.

Frank's theoretical formula (1908). — Professor Frank, in a communication published with von Richter's paper, defended his formula, on the ground that it held good over the range of conditions within which a locomotive customarily worked, and a year or two later endeavoured to support its validity by means of further experimental results [15]. This later paper [16] of Frank's is, however, chiefly of interest because in it he attempted also to establish on a theoretical basis a formula giving the horse-power in terms of the speed and the chief dimensions of the locomotive. Frank based this formula on the theoretical tractive effort of the locomotive at starting, adding and subtracting variable

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(14) *Glasers Annalen*, 1911, vol. 69, p. 240.

(15) *Glasers Annalen*, 1907, vol. 61, p. 233.

(16) It was translated into English and printed in the *Bulletin of the Int. Railway Congress*, October 1908, p. 1116.

quantities to represent the different factors coming into play at speeds above the critical at which the boiler fails to supply the steam necessary to maintain the full tractive effort. This critical speed he gave as

$$V_1 = \frac{A\sqrt{RH}}{T}$$

where R is the grate area and H the heating surface in square metres, V_1 is the critical speed in kilometres per hour, T is the load on the driving wheels in tons, and A is a coefficient which he estimated as 4.133 for a 0-6-0 goods locomotive, 4.056 for a 2-4-0 passenger locomotive, and 3.985 for a 4-4-0 express compound locomotive. Up to this speed the rated tractive effort formula was to be applied. Above it, Frank assumed that the steam production increased directly as the speed. He also supposed that it would vary as the logarithm of the boiler pressure and as the product of the grate area and the square root of the heating surface for different locomotives, assuming that « the utilisation of the fuel is, for the same grate area, the more favourable the greater the heating surface » [17]. The influences tending to reduce the power of the locomotive were first, the resistance to flow of the hot gases through the boiler tubes, which he supposed to be dependent on the square of the speed, the length of the smoketubes, and the inverse of their internal diameter. This would require the subtraction of a factor depending on the cube of the speed in the power formula. Second, there was the reduction in performance due to throttling through the regulator and at admission [18]. This he supposed to vary with the square of the speed and inversely as the logarithm of the boiler pressure. But to allow for increased priming at higher rates of steam consumption (the formula was intended, of course, for saturated steam locomotives) the total loss was made to depend on the cube of the speed, thus also conveniently simplifying the formula.

Although of no value to-day, some attention has been devoted to Frank's theoretical formula because it indicates the general lines which most theoretical discussions of the problem followed, and at the same time it will perhaps, in the light of what follows, reveal the great difficulties of approaching the problem on these lines without first an accurate knowledge of the factors affecting locomotive performance such as is not yet available, and second a much more uniform application of that knowledge in the shape of universally accepted rules of good design.

Each of the factors in Frank's formula was, of course, accompanied by an experimental constant, and such agreement as Frank found between his curves and actual test results was dependent on his choice of values for these constants. Indeed, since for every type of locomotive extensive experimental results are necessary in order to establish these constants, there appears to be little advantage in using the formula in place of the experimental results. Frank's idea was that formula and test should check each other, and for this there is some measure of justification when ordinary road tests are made, in view of the uncertainty that any individual test result represents the maximum or any specified proportion of the locomotive's output, but the constants in a theoretical horse-power formula of this type should really be based on fundamental experimental results relating to the individual factors in the formula, applicable to all locomotives of normal design.

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(17) *Glasers Annalen*, 1908, vol. 62, p. 15.

(18) Frank, like other theoreticians, ignored the much more important loss due to throttling at exhaust.

Work of Strahl. — Richter's formula was immediately taken up by Strahl, who in 1908 published (19) a long series of articles entitled « Die Anstrengung der Dampflokomotiven », subsequently followed by many other valuable studies of this and kindred problems which entitle him to a high place amongst locomotive engineers. The particular value of the articles cited lay in the fact that instead of advancing a formula or theory and assembling his facts around it, he was content to discuss the various factors influencing locomotive performance from a critical point of view. For instance, he discussed at length the question of the ratio of the heating surface to grate area, and appraised very shrewdly the value, or lack of value, of the hitherto widely accepted criterion that the greater this ratio the higher the boiler efficiency. The facts are, of course, well enough known to-day, but it will be evident from what has already been written that at that time there was much confusion of thought on the subject, which was a hindrance to the more exact knowledge of locomotive horse-power.

Strahl started from the basis that a locomotive boiler can normally evaporate a certain maximum quantity of steam, which is directly dependent on the grate area, but practically independent of the calorific value of the fuel (since the quantity of air required for the production of the same total amount of heat remains practically the same), and of the heating surface (since the efficiency of the boiler is only affected to an increasingly small degree by increase of the ratio of heating surface to grate area). He gave as an average figure for the maximum rate of evaporation 3 500 kgr. of steam per sq. metre of grate area per hour (equivalent to 716 lb. of steam per sq. ft. of grate area per hour), and pointed out that the hardness, size, and weight of the fuel would affect this figure more than its calorific value. The actual quantity of steam generated depends, within the limits set by this maximum value, on the quantity of air drawn through the grate, that is, on the pressure in the blast pipe, which, in turn, is dependent on the quantity of steam used. Strahl satisfied himself on this point by removing the valves from a locomotive and studying the effect of varying the regulator opening, the steam passing directly through the steam chest to the blast pipe and chimney. The maximum quantity of steam generated corresponds to a maximum steam consumption, but is independent of whether this consumption is at a low speed and late cut-off, or at a high speed and early cut-off, except in so far as the boiler efficiency is affected thereby.

At the speed at which any locomotive is primarily designed to run there is, however, a limited range of cut-off at which the steam supplied is used to the best advantage, and Strahl postulated that this speed and cut-off also corresponds to the maximum evaporative performance of the boiler, and hence demanded a definite relationship between the cylinder volume and the grate area. Any serious deviation from this relationship must result in a reduction of the maximum horse-power of the locomotive, and Strahl claimed that such a criterion was an essential condition in any horse-power formula such as Richter's. His criterion is given by

$$n' = C \frac{R}{J}$$

where n' is the number of revolutions per minute at the most favourable speed, R is the grate area in square metres, and J is the volume in cubic metres of one cylinder of a two-cylinder simple locomotive or one low-pressure cylinder of

(19) *Organ für die Fortschritte des Eisenbahnwesens*, 1908, p. 337.

a four-cylinder compound locomotive. He arrived at the essential factor C by extensive study of available test results and gave it the following values : 11 for saturated steam simple-expansion locomotives, 12 for two-cylinder compound locomotives, 13 for four-cylinder compound locomotives, and 15 for superheater simple-expansion locomotives. Subsequent experience has proved that Strahl's criterion is invalid, since the hypothesis regarding the most favourable speed on which it is based does not correspond to reality.

Strahl also commenced at this time his study of the losses of power in the cylinder, especially due to throttling at admission, and their effect on the mean effective pressure. In his 1908 articles, however, he expressly stated that his theoretical discussion of the problem could not be sufficiently exact to be capable of application to calculations for specific cases. He claimed only that it would help to give a clearer picture of the general effect of throttling and its influence on the use of the steam supplied by the boiler. He carried these studies much further, however, during the following years, and eventually published a book on the subject, to which reference will be made towards the end of this note.

III. — EARLY EXPERIMENTAL WORK.

Germany. — In order to appraise the value and to realise the limitations, particularly of the German work of which an account has been given, it is necessary to consider the expemental data available at the time. For, despite the attempts which were being made to place the estimation of locomotive horse-power on a theoretical basis, it is evident that ultimately actual values were in all cases derived from practical test data. This was in a sense a golden age for the theoretician of a type especially characteristic in Germany, and this fact possibly accounts for the predominance of German work during this period. Discourses [20] on locomotive performance were composed on the assumption that given a couple of experimental results to start from, theory would do the rest. The experimental results available were insufficiently exact or numerous to reveal what in the light of these theories could only have been regarded as hopeless inconsistencies.

Most of the earlier German work was based on a series of locomotive trials carried out at the beginning of the eighties of last century at the instigation of the Prussian Minister of Public Works [21]. These trials were designed to determine the maximum performance of three standard locomotives at different speeds on different gradients. No dynamometer car was available, however, and the work of the locomotive was estimated by means of Clark's train resistance formula based solely on the weight and speed of the train. Frank subsequently attempted to estimate the resistance more accurately, but had to make assumptions regarding the composition of the trains as the weights only were given in the published data. In these circumstances it is not difficult to understand how he could have arrived at so simple a power formula and retained so much faith in it.

Further tests were carried out in Germany from time to time, some of which Frank himself made use of. Generally they merely provided the information that such and such a locomotive hauled a train of such and such a weight between two given points at a certain speed. The necessity of uniform conditions was realised, however, and it was

(20) See, for example, Obergethmann, *Glasers Annalen*, 1909, vol. 64, p. 228.

(21) *Organ für die Fortschritte des Eisenbahnwesens*, 1887, p. 103.

usual to select data which could reasonably be supposed to relate to steady performances. The extreme difficulty of securing really uniform conditions, even for a limited period, in an ordinary road test, was not realised at that time, and in reality the data used were so unreliable and the assumptions made so wide that almost any theory could be supported by the available test results.

America. — Probably the greatest activity in locomotive testing, then as at a later period, was in America, so much so indeed that a joint committee of the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association was formed to report on Standard Tests of Locomotives (22). But this testing was almost all comparative in character, largely due to the advent of the compound locomotive. The committee's report therefore was designed only to ensure that the conditions in a comparative trial should be the same as between the individual runs, so that the fuel consumptions measured, which the railway managements were mainly interested in, should be truly comparable. No rules were laid down to govern the conditions under which measurement of power should be made and no attempt was made to suggest methods by which absolute measurements of performance could be made under constant conditions.

England. — In England the results of several series of locomotive tests were published, notably by Adams and Pettigrew (23) and by W. M. Smith (24) a dynamometer car having been used in the latter case in conjunction with the taking of indicator diagrams. W. M. Smith's tests were carried out « to obtain an idea of the fitness of five different classes of express passenger locomotive engines to perform a given duty », but the governing conditions in this, as in most contemporary trials, was to adhere as carefully as possible to a pre-arranged schedule time, the working of the engine being left to the driver's discretion. The data given included particulars of the drawbar and the indicated horse-powers on various gradients at particular moments, but in view of the continually varying conditions and the absence of any separate determination of the internal resistance of the locomotive, it is scarcely surprising that an editorial article in *The Engineer* (25) commented on the results as follows : « We have only to examine with care the tables and diagrams... to appreciate the futility of the whole thing... The attempt to deduce any law or co-ordinate any facts would lead to lunacy. We encounter every moment the most baffling contradictions. The inconsistencies are amazing; the incompatibilities perplexing.

IV. — EARLY ATTEMPTS TO EVOLVE SCIENTIFIC BASIS OF TESTING.

The first attempts to put the testing of locomotives on a really scientific basis were those of Borodin and Loevy in Russia, and of Desdouits in France. In order to understand the significance of their work it is necessary to examine the underlying causes of the « baffling contradictions » referred to by *The Engineer*.

There are three bases of measurement of locomotive horse-power :

(1) *Indicated horse-power.* — This can be directly measured and is uninfluenced (26) by conditions of running. But is does not include the mechanical efficiency of the locomotive and there-

(22) See *Proc. Am. Rly. Master Mechanics Assocn.*, 1893, vol. 26, p. 22.

(23) *Proc. Inst. C. E.*, 1895, vol. CXXV, p. 282.

(24) *Proc. I. Mech. E.*, 1898, p. 605.

(25) *The Engineer*, 1898, vol. 86, p. 449.

(26) This statement is not strictly correct, but in considering the mechanical principles involved it may stand.

fore does not afford a basis for a complete evaluation of locomotive performance. Moreover no convenient direct method exists of integrating indicated horse-power during a test under variable conditions, and indirect methods are inaccurate, even if a large number of indicator diagrams be taken during the run.

(2) *Drawbar horse-power.* — This can be measured and integrated with a very high degree of accuracy by means of a dynamometer car. Railway managements like to have the performance of a locomotive expressed in terms of drawbar horse-power because it represents the power ultimately available for drawing carriages and wagons. But it is scientifically almost valueless as a basis of estimating locomotive performance because it excludes an unknown proportion of the work done by the locomotive in moving its own proportion of the weight of the train, which may actually vary between zero and 100 per cent. according to the load behind the tender, the gradient of the road, and the acceleration of the train.

(3) *Horse-power at the rims of the driving wheels.* — This corresponds to the brake horse-power of a stationary steam engine. It includes the whole efficiency of the locomotive as a machine for doing work. It does not include the resistance of the locomotive as a vehicle; that is to say it would not evaluate any merits a locomotive might have due to low journal resistance or to streamlining. But these are properly matters of train design as a whole, as is particularly apparent in the matter of streamlining, and it is logical that they should be included in the resistance of the train and not in the efficiency of the locomotive. On a stationary locomotive testing plant it is this horse-power which is measured, plus, however, the journal friction of the driving wheel axles which rotate. In road tests there is no direct method of measuring this horse-power.

The equation of motion of a train may be written as follows :

$$F = \left[\frac{P + Q}{g} + \Sigma \frac{I}{R^2}\right]\frac{dv}{dt} + P\,(w_p + i) + Q\,(w_q + i)$$

omitting the term for the elastic oscillation of the train, which is negligible. F is the force at the rims of the driving wheels of the locomotive, producing motion; P and Q are the weights of locomotive and train respectively, and w_p and w_q their respective resistances to motion along the track; dv/dt is the acceleration of the train, g the acceleration due to gravity, and i is the gradient. $\Sigma\, I/R^2$ is the term giving the total inertia of the rotating wheels, I being the moment of inertia and R the radius of individual wheels.

Now if instead of the force at the rims of the driving wheels, the force at the drawbar be measured, the terms including the weight P of the locomotive must be omitted, and it is evident that unless the gradient and the acceleration of the train are known at the required moment, as well as the resistance of the locomotive as a vehicle, it is impossible to relate the performance of the locomotive, as expressed by the speed of the train and the weight of the carriages hauled, with its dimensional characteristics. If the gradient and the indicated horse-power be given, as in W. M. Smith's tables, it is still essential to know the acceleration of the train and the internal machine friction of the locomotive.

The Belgian method of testing. — Reference has already been made to the work of Desdouits with the dynamic pendulum. It was at the beginning of the eighties' of last century that Des-

douits became interested in the then newly invented « inertia ergometer », as it is generally known in England, and during the succeeding twenty years he published accounts of many investigations carried out with its aid, which included measurements of locomotive resistance (27). The dynamic pendulum is suspended in the dynamometer car and sets itself at an angle to the normal proportional to the accelerating force acting on the train in the direction of travel, *independently of the gradient* (28). A recording mechanism causes the pendulum to scribe a curve, the ordinates of which, in the early form used by Desdouits, were proportional to the accelerating force. In the later forms of ergometer the mechanism is so arranged that the slope of the line described by the pen is proportional to the accelerating force.

This gives the sum of all the terms in the right-hand side of the equation of motion of the train except those due to the resistances of locomotive and train and the inertia of the rotating wheels. If, immediately after this measurement has been made for any particular speed, and before conditions have had time to alter, steam is shut off, the new rate of acceleration, which will usually be negative, will give the total resistance of the train. Thus, the equation of motion can be completely solved and the tractive force of the locomotive at the rim of the driving wheels determined, if the inertia of the rotating wheels be neglected.

Much later Doyen, chief engineer of the Belgian State Railways, adopted Desdouits' proposals (29) and developed them systematically into what became known as the Belgian method of testing. The tests were carried out under the variable conditions of an ordinary run, steam being shut off for a kilometre or so at a number of different speeds so as to enable the total work of the steam at the rims of the driving wheels to be calculated. Performance data based on this figure are truly comparable as between different locomotives (30), and herein lay the great advantage of the Belgian method of testing over the customary method of integrating only the drawbar horse-power. The degree of accuracy attainable, however, is not very high. In the first place, the measurements of the ergometer itself are not very reliable. Another objection is that the total resistance of the train must necessarily be measured when steam is shut off, whereas what is required is the resistance when the locomotive is under steam. Finally, the inability of the method to measure the forces due to the inertia of the rotating masses constitutes a major inaccuracy.

The rolling resistance of locomotive and tender can easily be obtained by subtracting from the total resistance of the train, as measured by the ergometer, the resistance of the carriages as measured by the dynamometer at the tender drawbar. The form of characteristic curve for a locomotive used by Doyen consisted of a curve of drawbar pull

(27) Nadal gives a list of references to Desdouits' papers, *Revue Générale des chemins de fer*, 1903, vol. 26, p. 285.

(28) On an incline the displacement of the pendulum from the normal under the static force of gravity is exactly balanced by the acceleration component in the direction of travel of the dynamic force of gravity. Thus if the train moves at a uniform velocity up a gradient, the ergometer registers an accelerating force equal and opposite to this dynamic component, which is due to the pull of the locomotive.

(29) *Bull. Int. Railway Congress*, February 1911, p. 145.

(30) Except in so far as widely differing conditions may throw the bulk of the work of the locomotives compared into different regions of efficiency.

based on standard rates of fuel consumption per sq. ft. of grate area (fig. 4). The standard rates were as follows, the figures being expressed in English units :

56	lb. per sq. ft.	of grate per hour	at speeds below	25	m.p.h.
65	»	»	»	37	»
84	»	»	»	50	»
107	»	»	»	62	»
121	»	»	»	75	»

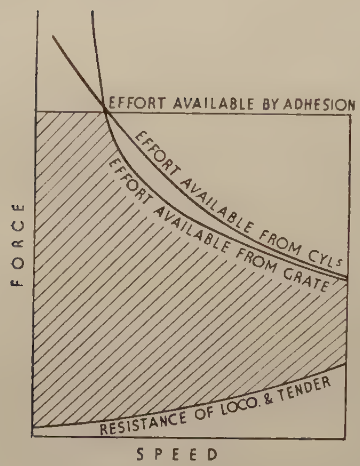


Fig. 4. — Doyen's characteristic curves.

The force at the rims of the driving wheels corresponding to each of these speeds was calculated by means of a constant value for the fuel consumption of the locomotive per horse-power hour measured at the rim of the driving wheels as determined from the trial results. The rolling resistance of locomotive and tender was plotted on the same diagram, and the lengths of the ordinates lying between the two curves give the available pull at the drawbar. This was replotted as shown, using an adhesion factor of 6.5 as the limit at low speed.

This may appear at first sight a somewhat roundabout way of obtaining a drawbar pull curve, but it must be remembered that the fuel consumption per drawbar horse-power hour, as determined by means of the dynamometer integrator, cannot be properly used as an absolute basis of comparison, since it is dependent on the weight of the train and the grading of the track. This fact, which is sometimes insufficiently recognised, cannot be too strongly emphasised, elementary though it is. The Belgian curve of drawbar pull is actually equivalent to the modern German « corrected drawbar pull », that is to say, the drawbar pull on a dead level track.

The Belgian method of testing has never been very successful, however. It set about the chief problem in the wrong way; that is to say, it attempted the impossible task of taking account of the changing conditions during a test run, instead of stabilising those conditions and thus eliminating a highly complex tissue of cause and effect.

French indicator tests. — In later French experimental work the indicator diagram was taken as the main basis of study of locomotive performance, and in 1903 Nadal, the engineer of the French State Railways, commenced the publication of the results of a series of locomotive tests [31] which included curves of indicated horse-power on a basis of speed, for various conditions of cut-off and steam chest pressure. In actual fact, however, these curves were largely hypothetical. As an inevitable result of the varying conditions under which the locomotives were running the indicated horse-powers plotted were erratic; moreover extrapolation was resorted to freely. It is for the latter reason that in some cases the curves show very high indicated horse-power at high speeds. Nadal recognised that the upper regions of some of his sets of curves lay outside

(31) *Revue Générale des chemins de fer*, 1903, vol. 26, p. 285.

the range of possibility. He mentions the limit of boiler performance but actually obtained a practical curve of performance by the somewhat arbitrary device of connecting up points corresponding to the falling steam chest pressure at increasing speed, obtained with a constant but restricted regulator opening. Nadal also carried out measurements of locomotive resistance by the method of rolling down a gradient.

Nadal's work is a good illustration of the inevitable limitations to what can be learned under the fortuitous conditions of road testing under ordinary service conditions, even when the effects of acceleration, gradient, and locomotive resistance are avoided by basing deductions upon the indicated horse-power.

Sanzin's Austrian tests. — In Germany the search for a simple horse-power formula gave place to more intensive experimental work chiefly under the influence of Dr. Rudolf Sanzin, of the Austrian Railways, whose experiments were widely published in Germany. Dr. Sanzin made a special study of locomotive tractive effort, using the equation of motion of a train. He also carried out, like Nadal, extensive measurements of locomotive resistance by the method of rolling the locomotive down a gradient under the action of gravity (32), and he proposed and used the same method for determining the resistance due to angular acceleration of the rotating wheels (33). He pointed out that for this purpose it is only necessary to make two rolling tests at the same speed on different gradients. It then follows from the equation of motion (page 164) that

$$-w_p\,P = \left[\frac{P}{g} + \Sigma\,\frac{I}{R^2}\right]\frac{dv_1}{dt} + i_1 P$$

$$= \left[\frac{P}{g} + \Sigma\,\frac{I}{R^2}\right]\frac{dv_2}{dt} + i_2 P$$

where dv_1/dt and dv_2/dt, and i_1 and i_2 are the respective accelerations and gradients. Equating the two right-hand side expressions we have

$$\Sigma\,\frac{I}{R^2} = \left[\frac{i_2 - i_1}{\dfrac{dv_1}{dt} - \dfrac{dv_2}{dt}} - \frac{1}{g}\right]P$$

The same gradient may be used if in the second case the locomotive or train is rolled up the grade instead of down.

Sanzin never actually attempted in his tests of locomotive performance to secure constant conditions, but he was fully aware of the sources of confusion and inaccuracy inherent in tests under variable conditions. He introduced the « equivalent drawbar pull » which is still used as the basis of characteristic performance curves in the modern German method of testing, and based his tractive effort curves (34) on it. The equivalent drawbar pull is the drawbar pull which would be exerted for a given power output at constant speed on a level track, but whereas such conditions are actually approximated to in the modern German road tests, Sanzin had to calculate the equivalent drawbar pull from results obtained under unsteady conditions on a graded route. To do this he used the equation of motion of a train in the form

$$F_e = F_d + Q\,(\pm i \pm b) + (L + T)\,(\pm i \pm b)$$

where F is the equivalent drawbar pull on a level track at constant speed, F_d is the actual observed drawbar pull, or resistance of the train, Q is the weight of the train, L and T are the weights of locomotive and tender respectively, i is the resistance of the gradient per unit of weight, and b is the accelerating or retarding force per unit of weight. In calculating the last-mentioned value he allowed for the inertia of the rotating

(32) *Z. V. D. I.*, 1911, p. 1461.

(33) *Elektrische Kraftbetriebe und Bahnen*, 1919, pp. 81-7.

(34) *Z. V. D. I.*, 1906, vol. 50, p. 118.

masses; assuming that they amount to about 8 per cent. of the total mass of the train, then b in kilogrammes per ton is given by

$$b = 0.1101\gamma$$

where γ is the acceleration in metres per second per second. He measured the acceleration by means of the tangent to the speed-time curve recorded in the dynamometer car. Such a method of measuring the acceleration is, of course, very unreliable, so that the allowance for the inertia of the rotating masses was perhaps a refinement more justified in theory than in practice.

Figure 5 reproduces the curves obtained by Sanzin in 1905 for a four-coupled compound express locomotive. A curve of drawbar horse-power is included on this diagram, but in general Sanzin gave only the drawbar pull or tractive effort curve, and this has been the more usual practice in modern times, since the values of tractive effort are more convenient for the purpose of calculating train speeds and times. But the horse-power curve can, of course, be immediately obtained from the tractive effort curve by simple multiplication. It has the advantage of showing at a glance the most favourable speed, from the point of view of power output, for the locomotive concerned. Figure 5 is of interest because

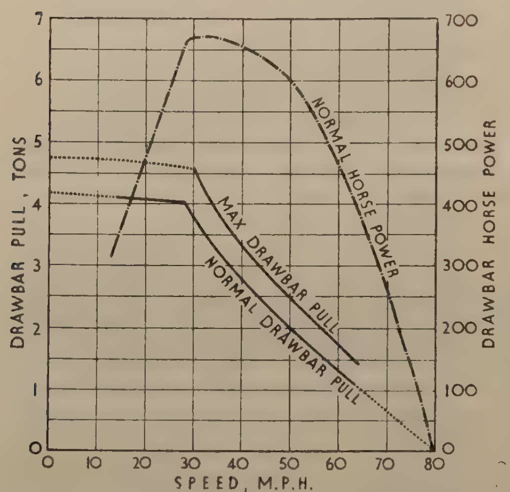


Fig. 5. — Performance curves (Sanzin).

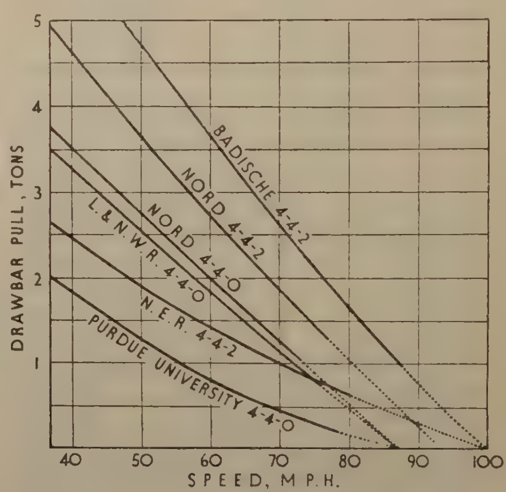


Fig. 6. — Collated drawbar pull curves (Sanzin).

it shows two tractive effort curves for the same locomotive and raises the problem of the criterion by which characteristic performance curves should be selected. Naturally a locomotive can exert a wide range of tractive effort at any given speed according to the regulator and cut-off positions. The lower curve is given by Sanzin as for average daily performance and the upper as a maximum performance. The distinction is an important one, and is still used today by many authorities, but such criteria lack any kind of precision. What exactly constitutes average daily performance may, and indeed does, vary considerably according to different administrations. Until the introduction of constant test conditions it was impossible to establish any precise standard

of operation on which to base such performance data, and even if such a standard had been envisaged, the prevailing conditions of testing involved so many inaccuracies and uncertainties that it could not have been put into practice. Curves of drawbar pull and speed, such as Sanzin's, obtained from ordinary road tests, are therefore generally mean curves drawn more or less arbitrarily through widely scattered points, and are particularly uncertain in the upper region of speed. Thus, in the paper to which reference has been made, Sanzin included a diagram, reproduced in figure 6, collating the drawbar pull curves of a number of locomotives in the upper region of speed, from a variety of published test results. A mere inspection of these curves, in the light of our knowledge of the locomotives concerned, is sufficient to indicate that they are of little scientific value, and that the extrapolations in the highest region of speed bear no relation whatever to actual fact. Such a diagram as this embodies not only the margin of uncertainty of each individual road test, but the still greater uncertainty as between road tests carried out by different administrations under different conditions. Further, since the factors affecting locomotive power become increasingly uncertain as the speed increases, extrapolation into a higher region of speed from a lower region is, as we have already seen in the case of Professor Dalby's curves, figure 2, really quite inadmissible.

Sanzin may be regarded perhaps as the last of the great locomotive experimentalists to work with the method of road tests under variable conditions. His work was not merely comparative, but comprised a systematic study of locomotive performance and efficiency (35). He was also a pioneer in the working out of systematic diagrams for the calculation of train speeds and times on various gradients, based on his locomotive tractive effort data. His work had a beneficial influence on the somewhat theoretical trend which the study of locomotive horse-power had hitherto tended to take in Germany.

Genesis of the Russian experiments. — Borodin's early experiments with a stationary testing plant and his paper before the Institution of Mechanical Engineers (36) in 1886 have already been mentioned. To Russia also belongs the credit of first carrying out tests under constant conditions on the road; but whereas Borodin's test plant experiments were only tentative, the real beginning of what later became the American method of testing being Professor Goss's experiments at Purdue, Loevy's road tests were the commencement of a consistent development of technique during some forty years. For most of this time little attention was paid to this work in other countries, but eventually the methods elvolved were adopted and perfected in Poland and Germany and became the modern European method of testing. A special section will be devoted to a description of this method and its variants at a later stage, but for the sake of historical continuity its genesis in Russia is referred to here. Loevy actually used an auxiliary locomotive to assist in maintaining constant conditions, but generally speaking the principle followed in the Russian experiments was to choose a suitable length of track and to use only the dynamometer car brakes as a controlling force. Loevy's experiments did not attain success, but his work was taken up by Professor Lomonossoff, to whom the chief credit for the evolution of this method of testing belongs, and in 1900 Professor

(35) See, for example, article on « Der Wirkungsgrad der Dampflokomotiven », *Z. des österr. Ing. und Arch. Vereins,* 1910, p. 725.

(36) *Loc. cit.*

Lomonossoff accomplished the first successful test under constant conditions. In 1905 the method was fully established, and in 1908 the Russian experimental bureau was set up.

The year 1905 may be regarded conveniently as the commencement of a new experimental era in the measurement of locomotive horse-power, for in that year also the first locomotive tests of the Pennsylvania Railroad in cooperation with the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association on the new testing plant at Louisiana Purchase Exposition, St. Louis, were published. Thus two quite distinct and independent lines of development were initiated, which have persisted to the present day. They are distinguished by a fact of considerable importance. Generalised formulæ and tables have been developed from the American results, whereas the Continental experimental workers have so far consistently held that generalised formulæ or data are not reliable and that the best that can be done in drawing up a new design is to use the test results from a locomotive of as nearly similar a design as possible, especially in regard to cylinder and valve gear arrangement.

A probable reason for this difference is that the American data have been largely evolved and used by two very large firms of locomotive builders [37]. In such matters as cylinder and valve gear design these firms would naturally be dealing with relatively standardised conditions, and generalised formulæ can possibly be applied with a greater degree of confidence to locomotive types designed and constructed by the same builders. At the same time, it is worth noting that a greater variety of valve motions are in common use in America than in Europe.

[37] The Baldwin Locomotive Works and the American Locomotive Company.

V. — THE AMERICAN METHODS OF TESTING AND HORSE-POWER CALCULATION.

The Pennsylvania testing plant. — After the St. Louis tests the Pennsylvania Railroad Company's testing plant was permanently established at Altoona, and bulletins giving full details of tests on various modern American locomotive types have since been regularly issued. The general principle of testing is as follows. The reversing lever is set so as to give the shortest possible cut-off and the regulator is opened wide. A test at low constant speed is then run under these conditions. The cut-off is then advanced by a certain percentage and another test at the same speed is run. Successive advancements of cut-off are made until the limit of adhesion is reached or the boiler is no longer able to supply sufficient steam to maintain pressure. The speed is then increased and a new series of tests is made at increasing cut-off until the whole range of operation of the locomotive is covered.

This method permits of the construction of a series of tractive effort-speed curves [38] for various cut-offs, together with a limiting curve at full boiler capacity giving the maximum tractive effort. Figure 7 gives an example of such a set of curves for the well-known Pennsylvania K4s Pacific type locomotive, having 6 ft. 8 in. driving wheels. A curve of maximum horse-power has been added.

Most of the earlier tests at St. Louis, as a matter of fact, fell somewhat short of

[38] These are referred to as drawbar pull-speed curves in the Bulletins of the Pennsylvania Railroad. It must be emphasised, however, that the force actually measured is the tractive force on the axlebox guides, which is only 2-3 % less than that at the driving wheel rims. The use of the term « drawbar pull » in connection with stationary plant tests is to be deprecated as it causes much confusion.

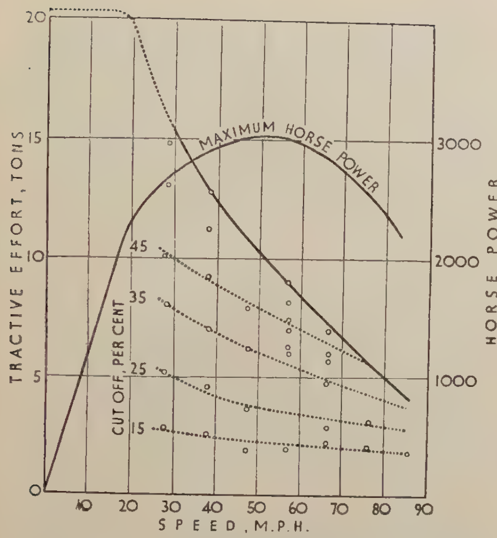


Fig. 7. — Tractive effort characteristics (Pennsylvania test plant).

this programme as the number of individual tests was limited, and only one or two at the higher speeds were run at the maximum evaporative rate of the boiler. For this reason a process of extrapolation had to be resorted to in order to obtain the curve of maximum tractive pull. Two sets of curves were used, namely, steam consumption per indicated horse-power hour, and indicated horse-power, for the several speeds, both on a basis of cut-off. The maximum evaporative capacity of the boiler having been determined from one high-speed test, it is then only necessary to select for each speed the point at which the product of indicated horse-power and steam consumption, as given by the extrapolated curves, is equal to the maximum rate of evaporation (39).

(39) This method of extrapolation is open to the grave objection that the power of locomotives in the lower range of speed is limited more often by cylinder size than by the evaporative capacity of the boiler. This point will be specifically referred to later on.

The Baldwin tractive effort curves (1912). — The Baldwin Locomotive Works published in 1912 a set of generalised tractive-effort-speed curves (40). These are actually merely an application of Professor Goss's law,

I.H.P. $= 0.43 \times$ heating surface (sq. ft.),

slightly modified. If the horse-power of a locomotive is fixed at a certain figure, it is evident that above a certain speed a diminishing proportion of the rated cylinder tractive effort (41) can be realised. This critical speed and the proportion of the rated tractive effort at any high speed will depend only on the ratio of the tractive effort to the heating surface, and the Baldwin curves are therefore drawn for a series of values of this ratio. It is important, however, to realise that although cylinder dimensions enter into the tractive effort values, they do not affect the horse-power which the locomotive is considered to give, so that the Baldwin method is in principle no advance upon the early German formulæ based simply on the heating surface.

The modifications of Professor Goss's law are as follows. In the first place, instead of the indicated horse-power the horse-power at the rim of the driving wheels is used as the basis. It is assum-

(40) « Locomotive Data », Baldwin Locomotive Works, Philadelphia, Pa.

(41) The rated tractive effort of a two-cylinder simple locomotive is given by the formula $0.85\ Pd^2s/D$, where P is the boiler pressure in pounds per square inch, d is the diameter of the cylinders, and D of the driving wheels, in inches, s is the piston stroke in inches, and 0.85 is a factor to allow for throttling of the steam and machine friction. It is obtained by equating the work done by the steam acting on the pistons and that done by the tractive force at the rim of the driving wheels through one revolution of the driving wheels.

$$\text{Horse-power} = \frac{\text{tractive effort} \times \text{miles per hour}}{375}.$$

ed, following Professor Goss, that an evaporative rate of 12 lb. of water per square foot of water heating surface per hour will represent the boiler power for both saturated and superheated steam. It is further assumed that the engine has a constant consumption at all speeds of 28 lb. of saturated steam or 21 lb. of superheated steam per horse-power hour at the rim of the driving wheels. Thus, for saturated steam the factor $12/28 = 0.43$ is the same as was given by Professor Goss, though the horse-powers are measured at different points, whilst for superheated steam the factor is modified to 0.57. At speeds below 30 m.p.h. an allowance is made for a lower maximum rate of evaporation, the upper horizontal portion of the horse-power curve being joined to the straight limb in the adhesion range, by a smooth curve. The resistances of locomotive and tender are given by the formula,

$$R = 4.3 + 0.0030\ V^2$$

where V is the speed in miles per hour, whence the drawbar horse-power may be calculated.

A probable reason why the Baldwin curves are based on the power at the rail instead of on the indicated power is the difficulty of estimating the internal machine friction of a locomotive. The Pennsylvania tests give much higher losses on this account than Professor Goss's figure of 3.8 lb. per sq. in. constant mean effective pressure — up to four times as much even for four-coupled locomotives. The figures are very erratic, however, and it has not been possible to relate them to any formula. These losses include, of course, the journal, windage, and rail resistances of the driving wheels, which should be excluded from the power at the rim of the driving wheels [42], but even so the Baldwin formula tends to give, for modern locomotives with large boilers, rather high values for indicated horse-power if these be obtained by adding suitable values for the machine friction. Indeed, as will appear in a later diagram, the results are comparable with those for indicated or cylinder horse-power obtained by the later American methods.

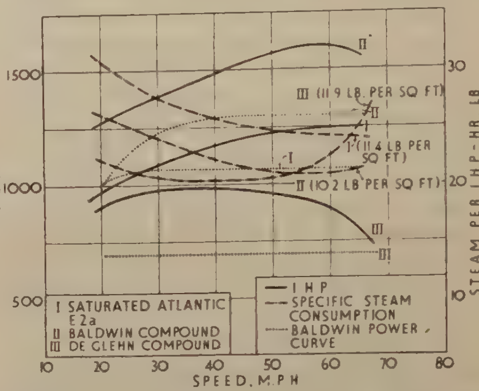


Fig. 8. — Specific steam consumption and I.H.P. for three locomotives tested at St. Louis.

Figure 8, which gives curves of specific steam consumption and indicated horse-power for three of the earlier saturated express locomotives tested at St. Louis and Altoona, shows clearly that the assumptions underlying the Baldwin method are far from correct for all locomotives. These curves correspond to the maximum power of the locomotives, as deduced by the method of extrapolation described above. The actual maximum rate of evaporation is given in figures alongside the steam consumption curves, and it will be seen that this varies considerably, and in the case of the compound locomotive built by the Baldwin Works itself, falls considerably short of the standard rate of 12 lb. per sq. ft. of heating surface per hour. Both the steam consumption and indicated horse-power curves represent far from constant values, and they do not follow a

(42) See page 164.

uniform law of variation. The horse-power curves given by the Baldwin formula are shown dotted, but it should be explained that, according to the Baldwin handbook, from 10 to 20 per cent. should be added in the case of compound locomotives.

Cole's ratios (1914). — F. J. Cole published his so-called « locomotive ratios », as used by the American Locomotive Company, two years later, in 1914 [43]. Cole reverted to the older practice of reckoning in terms of horse-power rather than tractive effort. For the purpose of calculating the power of an existing locomotive his method was the opposite of the Baldwin in that it was based solely on the cylinder tractive effort. The basis is a table of empirical speed factors, derived from a study of test plant results.

Figure 9 gives the indicated horse-power-speed curves for saturated- and superheated-steam locomotives based on the Cole constants. These curves are based on piston speed, but a scale of miles per hour has been added for a locomotive having 80-in. driving wheels and 26-in. stroke. The corresponding speed factors giving the percentage of the total tractive effort available at each speed are also tabulated in the American

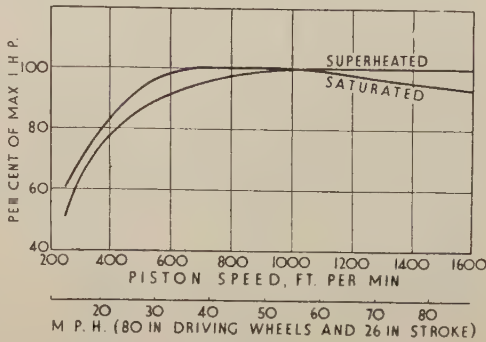


Fig. 9. — Horse power curves (Cole's constants).

Locomotive Company's handbook and the maximum cylinder horse-power must therefore be calculated at the appropriate speed and using the corresponding speed factor as a multiplier of the rated tractive effort. For example, for superheated steam

$$\text{I. H. P.} = \frac{0.85\ P \times 0.445 \times 1\,000 \times 2A}{33\,000} = 0.0229 \times P \times A$$

where P is the boiler pressure in pounds per sq. in. and A is the area of the piston in square inches. The factor 0.85 is the usual proportion of the boiler pressure taken in the rated tractive effort formula, and 1 000 (ft. per min.) is the piston speed at maximum horse-power. The figure 0.445 is the speed factor.

Although the evaporative capacity of the boiler does not enter into the Cole horse-power formula, yet it was the boiler to which Cole devoted most attention in his « locomotive ratios ». The aim, however, was to enable the designer of a new locomotive to design a boiler which should be able to supply at all speeds just sufficient steam to develop in a given set of cylinders the horse-power deduced as above. Such a boiler he described as having 100 per cent. capacity. In order to link boiler and cylinder horse-power together in this way standard steam consumption rates of 27 lb. per I.H.P.-hour for saturated steam and 20.8 lb. per I.H.P.-hour for superheated steam were assumed. But Cole went much further than specifying an overall rate of evaporation for the boiler heating surface. He appor-

[43] « Locomotive Ratios », F. J. Cole, *Bulletin* No. 1017, 1914, American Locomotive Company. See also *Locomotive Handbook* American Locomotive Company, 1917, p. 54.

tioned the evaporation in the following way : firebox and combustion chamber, 55 lb. per sq. ft. per hour, 2-in. tubes, 18 ft. long, 15/16-in. spaces, 9.54 lb. and 2 1/4-in. tubes, 18 ft. long, 15/16-in. spaces, 10 lb. per sq. ft. per hour, the latter being base figures on which are calculated and tabulated values for various spacings and lengths. Cole also postulated that the gate area in square feet should be equal to the maximum horse-power divided by 30 in the case of saturated steam or 36.9 in the case of superheated steam.

Cole's ratios can, of course, be used to calculate the evaporative capacity of an existing boiler, and their significance lies in the fact that, unlike all the horse-power formulæ hitherto evolved, they go some way towards taking into account individual factors in design. These factors, as has been indicated, are confined to the boiler. Broadly speaking, and in normal circumstances, the detail design of the engine has a greater effect on locomotive power than the detail design of the boiler, so that in a sense Cole's ratios begin the refinement of horse-power calculation at the wrong end. Unfortunately, however, the factors affecting locomotive performance are so complex and difficult to measure that no simple way has yet been found of taking into account any dimensions of the engine other than cylinder diameter and stroke [44]. Beyond expressing the result as so much more or less than 100 per cent. capacity, however, Cole established no rules by which the effect of boiler capacity on cylinder horse-power could be determined.

To calculate drawbar horse-power the American Locomotive Company gave the internal machine friction as equal to 25 lb. per ton of weight on the driving wheels for all speeds, track resistance included, the rolling resistance of the engine and tender carrying trucks as the same as for carriage resistance, for which empirical values, based on test data, were tabulated, and the head air resistance as equal to $0.002\ V^2A$, where V is the speed in miles per hour and A the sectional area, assumed to be 120 sq. ft. It will be noticed that by this method the rolling resistance of the driving wheels is included in the machine friction and excluded from the resistance of the locomotive as a vehicle. This makes it impossible to calculate the horse-power at the rim of the driving wheels, but the results obtained after allowing for machine friction by this method correspond exactly to the dynamometer horse-power obtained on a stationary test plant on which as a rule only the driving wheels rotate.

Kiesel's formula (1915). — In the following year Kiesel's formula, based entirely on the test plant results obtained by the Pennsylvania Railroad, of which he was Assistant Mechanical Engineer, was published [45].

Kiesel's formula, like the Baldwin method, assumes to start with a constant boiler evaporation. But, instead of assuming a value for the specific steam consumption, the Kiesel formula evaluates independently the mean effective pressure. This, indeed, is the crux of the method. The formula is,

$$\text{Mean effective pressure} = \frac{2\ P}{1 + E}$$

where P is the cylinder admission pressure (say 10 lb. per sq. in. less than the boiler pressure) and E is the expansion ratio. Thus the mean effective pressure is expressed, not directly in terms of the speed, but in terms of the expansion ratio. This expansion ratio, however, is

(44) Strahl's formula for mean effective pressure will, however, be referred to later.

(45) « Principles of Locomotive Operation », A. J. Wood, New York, 1925, 2nd ed., p. 31.

not the indicated cut-off, but the ratio of the weight of a cylinder full of steam to the weight of steam supplied per stroke on the basis of the assumed evaporation rate, which, of course, will be inversely proportional to the speed. Hence the mean effective pressure is linked indirectly with the speed. It is unnecessary to work out in detail here the derivation of the Kiesel formula, as it follows quite simply from the above explanation. The expression for the expansion ratio reduces to

$$\frac{1\,056\ \mathrm{MV}}{3\ \mathrm{KH}}\ w$$

where M is the « engine constant » d^2s/D, using the same symbols as in footnote (41), V is the speed in miles per hour, w is the weight in pounds of 1 cu. ft. of steam, K is the evaporation per hour per sq. ft. of heating surface in pounds, and H is the total boiler heating surface (fire side). Substituting this expression in the formula for mean effective pressure, the tractive effort is given by

$$\text{Cylinder tractive effort} = \frac{2\ \mathrm{PM}}{1+\left(\frac{110\ w}{3}\times\frac{\mathrm{MV}}{\mathrm{KH}}\right)}$$

which is the actual Kiesel formula. The indicated horse-power may be directly calculated from this.

For the constant K some figure must be taken, as in the Baldwin method, which represents the maximum rate of evaporation which the boiler can be expected to maintain in normal service. But in this case the evaporation must be reckoned in terms of the steam actually delivered into the cylinder, and not the total quantity of water evaporated, so that a lower figure must be employed. A. J. Wood, who first published Kiesel's formula, suggested 10 lb. of water per sq. ft. of heating surface per hour for saturated steam and 8 to 8.5 lb. for superheated steam, the total heating surface in this case including the fire side of the firebox, superheater elements, boiler tubes and superheater flues, or being reckoned as the fire side of the evaporation surfaces plus six times the fire surface of the firebox. These are known as Wood's constants.

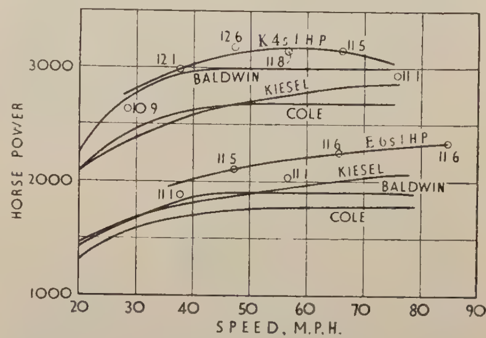


Fig. 10. — Horse-power curves for Pennsylvania locomotives.

In figure 10 are shown for comparison the horse-power curves for two contemporaneous American locomotives, the E6s superheater « Atlantic » type, and the K4s superheater « Pacific » type. The test curve is obtained from the stationary test plant results, and in this case extrapolation has not been necessary, actual tests at rates of evaporation between 11 and 12 lb. per sq. ft. per hour having been made over a fairly wide speed range. The precise rates of evaporation are shown alongside each test point and the curve is drawn accordingly. The other curves are calculated respectively by the three methods just described.

To calculate the resistance due to internal friction Kiesel gave the following formula :

$$R = [22 + 0.15\ (n - 1)\ V]\ Q$$

where Q is the weight on the driving wheels in tons, n is the number of coupled axles, and V is the speed in

miles per hour. By deducting the power absorbed in this resistance from the horse-power given by the Kiesel tractive effort formula, the horse-power at the rim of the driving wheels is obtained, and Kiesel preferred to work with this, including the rolling resistance of engine and tender (assumed equivalent to three cars) in that of the train. A separate term must, however, be employed for head wind resistance of the locomotive, for which Professor Goss's formula

$$R = 0.1 V^2$$

is recommended.

Lipetz's curves (1933). — In 1933, Mr. A. I. Lipetz, consulting engineer to the American Locomotive Company, published [46] a new method of tractive effort calculation, intended to bring Cole's method up to date, as the latter gives rather low values for locomotives having modern types of superheaters, feed water heaters, and valve motions. It will be remembered that Cole's original method depended only on the cylinder tractive effort, so that the boiler evaporation factors which constituted his most valuable contribution to the subject, did not enter into the horse-power calculations. Lipetz's method, on the other hand, depends solely on the boiler. It is, in principle, a modification of the Baldwin method, with the advantage that the evaporative power of the boiler can be estimated more exactly on the basis of Cole's ratios.

It differs essentially from the other methods in discarding the constant rate of evaporation as the criterion of maximum performance, Lipetz maintaining that in practice locomotives are not regulated so as to generate a constant amount of steam. He justifies this by plotting curves of evaporation rate for various locomotives tested at Altoona, including the K4s and E6s, taking the maximum performance at each speed. The curves are similar in shape, showing an increase with speed up to a certain limit, and a subsequent falling off, but they vary considerably in their numerical values. This, of course, is due to the fact that only a limited number of tests of each locomotive can be made, and since the test conditions were not always chosen with the primary object of ascertaining the maximum performance, such curves may indicate nothing more than the nature of that choice. Actually the Pennsylvania method of calculating the maximum performance is, as has already been mentioned, to assume that the maximum rate of evaporation could have been attained at the lower speeds had tests been run at a sufficiently high drawbar pull. On the other hand, consideration of the conditions of working for the maximum-power low-speed tests (cut-off and regulator opening) of some of the locomotives tested suggests that the maximum rate of evaporation could not possibly be reached in actual practice, and Lomonossoff's tests [47] confirm this for many locomotives, so that Lipetz's contention finds considerable justification.

Lipetz attempts to establish standard evaporation coefficients on the basis of road tests. But as road tests do not afford data as to the rate of evaporation at various speeds his method really resolves itself into nothing more than the selection of a standard horse-power-speed curve from the road performances of locomotives of the most modern type. This curve is then referred to the evaporative power of the boiler, calculated by Cole's constants but increased by 7 per cent. to allow for modern improvements, and the ratios so obtained can then be applied to any up-to-date loco-

(46) *Trans. A.S.M.E.*, 1933, vol. 55, RR-55-2. — See also *Bull. of the Int. Ry. Congress Association,* April 1935, p. 324.

(47) See diagrams in chapter VI.

motive type in order to calculate its horse-power from the boiler dimensions.

The artifice by which evaporative coefficients are obtained is as follows. The specific steam consumptions corresponding to various points on the standard horse-power-speed curve (plotted from road tests as mentioned) for locomotives as nearly similar as possible, were selected from the published results of the Altoona tests. By multiplying the indicated horse-powers by these specific steam consumptions total evaporation rates are obtained. These Lipetz expresses as percentages of the evaporation rate calculated by Cole's ratios, the maximum, as already mentioned, being 107 per cent. The resulting curve is

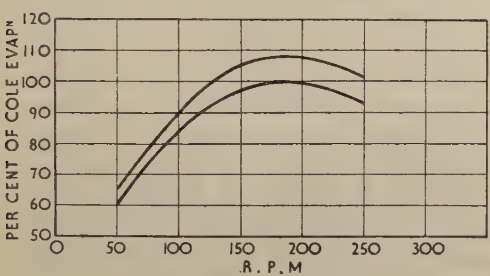


Fig. 11. — Lipetz evaporation coefficients.

reproduced in figure 11. The reason why the Altoona evaporation rates were not directly used has already been indicated; much better agreement was found between the maximum evaporation curves for various locomotives obtained in this way. It is important to notice, however, that these evaporation coefficients have no rational basis; they are, like the horse-power curve itself, a purely empirical expression of conditions of working as found in practice. But the evaporation coefficients are of no importance whatever so far as the method of power calculation is concerned since the same multiplication ratio or specific steam consumption by which they are obtained is then used as the divisor to obtain the horse-power from the Cole evaporation rate of other locomotives.

The specific steam consumption curve corresponding to Lipetz's evaporation coefficients is shown in figure 12. That it is not constant at any part of the speed

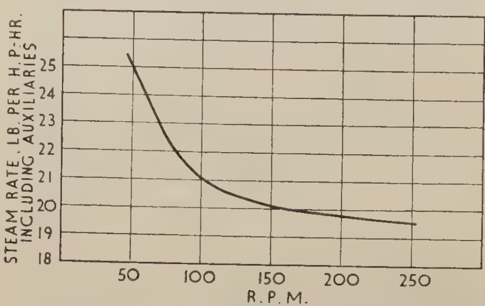


Fig. 12. — Lipetz specific steam consumption curve.

range does not necessarily imply that it is more correct than the Baldwin and Cole assumptions, since steam consumption may vary at any given speed according to the conditions of working, and Lipetz's empirical power curve postulates different conditions of working from the Baldwin and Cole constant evaporation criteria.

The application of Lipetz's method is quite simple. First the evaporative capacity of the boiler is calculated according to Cole's ratios. This is then multiplied by the coefficients given in figure 11 so as to give the actual evaporation at the corresponding speeds. By dividing this by the specific steam consumption rates in figure 12 the horse-power at each speed is obtained. In consequence of the very large size of some modern American boilers Lipetz suggested that a limit of 20 per cent. over and above the maximum horse-power given by Cole's method of calculation should be set, but this is the only provision he originally made for variations of the ratio of cylinder volume to heating surface.

In figure 13 are reproduced two sets of curves for a New York Central 4-8-2

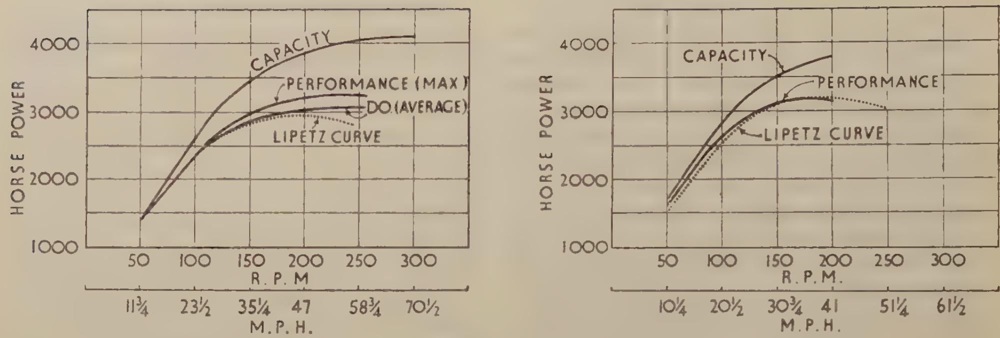


Fig. 13. — Comparison between Lipetz curves and test results.

and 4-6-4 locomotive respectively. These show close agreement between Lipetz's horse-power curve and the curves of average and maximum performance obtained from road tests of these locomotives. The « capacity » curves represent the performance of the locomotive at the point at which the boiler begins to fail to maintain steam supply, that is to say, the theoretical maximum performance.

It cannot fail to have been noticed that a very great difference exists between the cylinder performance characteristics as shown by these diagrams for modern American locomotives and as shown by the curves of Desdouits and Dalby, figure 2. Whereas the modern locomotive is capable of maintaining its indicated horse-power at or near its maximum value up to the highest speeds of testing, the cylinder horse-power curves for the earlier locomotives tended to decline as rapidly in the high-speed region as in the low-speed. The reason for this difference, of course, is mainly the improvement of valve motions and cylinder design; the locomotives represented by figure 13, for instance, have valve motions with about 8 1/2 in. of valve travel. But this predominant influence of engine design on the performance at high speed does not merely make a hard-and-fast difference between the performance of old and new locomotives. It causes the performance of different locomotives even of modern design to vary between wide limits in the range of speed above 200 r.p.m. This fact Lipetz fully recognised, for he stated that insufficient data are available on which to base a precise method of horse-power calculation above a speed of 200 r.p.m., since such a method would have to take into account, in addition to other factors, valve motion characteristics and areas of steam passages.

Recently Mr. Lipetz has published a supplementary paper (48) consequent upon his realisation that it is a serious disadvantage of his method, as originally formulated, that it depends solely on the boiler. Actually the locomotives whose performance data formed the basis of his original curves, all had very large boilers, following the practice of his firm. For many other classes of locomotives, however, the original Lipetz method gave horse-powers much lower than can be attained under the conditions for which they were designed, despite the fact that their boilers, according to Cole's criterion, have less than 100 per cent. capacity. According-

(48) *Trans A.S.M.E.*, 1934, vol. 56, RR-56-6.

ly he proposes a new criterion of boiler capacity, or « locomotive characteristic », namely

$$K = \frac{E_c}{V_{Pb}}$$

where E_c is the Cole evaporation, V is the volume of the cylinders and p_b is the boiler pressure. For a locomotive having a Cole boiler capacity of 100 per cent. the value of this constant is 14.26 and a series of curves at 50, 100, and 150 r.p.m. give correction percentages for values of this constant less than 14.26, by which the tractive efforts as calculated by the original method must be increased. These curves like the original curves, are based on an empirical study of performance data.

VI. — THE CONTINENTAL METHODS OF TESTING.

Russian method (Lomonossoff). — The genesis of the Russian method of testing and its importance as the first to be based on constant operating conditions have already been described (49). As finally perfected by Professor G. V. Lomonossoff, it was carried out as a matter of routine by a fully organised Experimental Bureau under Government supervision. Test reports on a variety of locomotives were published, some in English (50), and the whole method is fully explained and described, together with a number of detailed test reports, in Lomonossoff's classic work, « Lokomotivversuche in Russland » (51).

It has already been made clear that the necessity for constant conditions in locomotive testing arises out of the fact that a locomotive has no definite normal or maximum power, and that characteristic curves of power output must therefore be related to definite conditions of working, such as a certain rate of evaporation. In a normal run at fluctuating speed over an irregularly graded road it is almost impossible to determine the instantaneous rate of evaporation or steam consumption.

Professor Lomonossoff laid it down as the main end of a locomotive test, to determine the relationship

$$F = \Phi(z, V)$$

where F is the tractive force at the rim of the driving wheels, z is the rate of evaporation, V is the speed, and Φ is the function characteristic of the locomotive. This necessitates a series of tests at several constant speeds, and several constant rates of evaporation. This desideratum he succeeded in attaining by selecting suitable lengths of long continuous gradients and hauling trains of graduated weights. Several suitable lengths of continuous grade are available in Russia, though with frequent short stretches at less than the ruling gradient. These he compensated by brake applications in the dynamometer car. By this method the fluctuations of speed can be kept so small as to maintain a sufficiently constant rate of evaporation and engine working.

It is impossible, however, to compensate by means of the brake small accelerations due to slight changes of gradient, curvature, etc., sufficiently exactly to enable such accelerative forces to be disregarded in calculating the power at the rim of the driving wheels, and in 1911 Lomonossoff proposed a method, generally known as the Russian method of testing, by which such accelerative forces may be allowed for. It involves the separate measurement of the specific rolling resistance of both locomotive and train. The equation of motion of a train (p. 164) may be written separately for

(49) See chapter IV.

(50) « Tests of Different Types of Locomotives », Petrograd, 1916.

(51) Translated into German, 1926, *V.D.I.-Verlag*, Berlin.

the locomotive and carriages by introducing the drawbar pull, as follows :

For the locomotive

$$\left(\frac{P}{g} + \Sigma \frac{I_1}{R_1^2}\right)\frac{dv}{dt} = F_k - F_n - (w_p + i)\,P$$

For the train

$$\left(\frac{Q}{g} + \Sigma \frac{I_2}{R_2^2}\right)\frac{dv}{dt} = F_n - (w_q + i)\,Q$$

where P and Q are as before the weights of locomotive and train respectively and w_p and w_q their respective resistances, i is the gradient, dv/dt the acceleration, and F_k and F_n are the tractive forces at the rim of the driving wheels and at the drawbar respectively. In the case of steam locomotives it is possible by a suitable combination of empty and loaded cars to make $\Sigma I_1/R^2_1 = \Sigma I_2/R^2_2$ with sufficient accuracy for experimental purposes [52]. In this case, dividing the first equation by P and the second by Q, we have,

$$\frac{F_k}{P} - \frac{F_n}{P} - (w_p + i) = \frac{F_n}{Q} - (w_p + i)$$

or

$$F_k = \frac{P+Q}{Q}\,F_n + (w_p - w_q)\,P$$

Thus the force, and hence the power, at the rim of the driving wheels can be calculated accurately without measuring gradient or acceleration.

This method has proved extremely satisfactory. It is relatively inexpensive, since no second locomotive is required, and commercial loads can be hauled, but it depends entirely on there being available suitable lengths of track with a traffic density sufficiently low to make it possible to ensure absence of signal checks during testing periods. The continuous grade must be sufficiently long to provide a test duration of not less than 35-40 minutes at the quickest speed, since this is the least time in which the steam consumption can be accurately determined. (Even this, however, does not suffice to measure accurately the coal consumption, which must be spread over several individual test runs aggregating not less than 3 hours duration.)

It may seem a considerable complication to have to measure the specific resistance of locomotive and train separately at various speeds, but it can be done quickly, and, in the case of the train, in normal service by means of a dynamometer car. The resistance of the locomotive is determined by the method of rolling it down a gradient with the connecting rods uncoupled. The resistance at any speed is then given by the difference between the gravitational force and the product of the weight of the locomotive and the actual rate of acceleration at that speed (preferably measured by means of electrical contacts along the track). Figure 14 shows typical

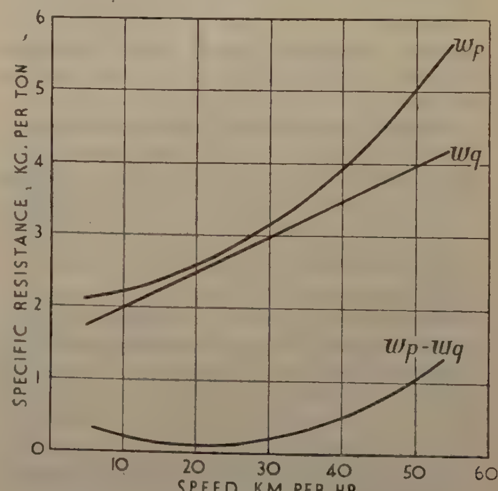


Fig. 14. — Typical resistance curves (Lomonossoff).

[52] But not for turbine or diesel locomotives with their much greater rotating masses.

curves of resistance obtained by Professor Lomonossoff for a 0-10-0 goods locomotive and train.

Varying rates of evaporation are secured by carrying out tests with various combinations of cut-off and regulator opening. Tests with full regulator opening are of the greatest importance, and should be made at cut-offs of 10, 20, 30, 40, and 50 per cent.; tests with partly opened regulator may be regarded as supplementary. As regards speed, Professor Lomonossoff's experience showed that four speeds were generally sufficient (15, 30, 45, and 62 m.p.h. for passenger locomotives ([53]) and 6, 12, 18, and 30 m.p.h. for goods locomotives). Under modern conditions in other countries two other speeds would have to be added, say 70 and 85 m.p.h., for express passenger locomotives, and 45 and 55 m.p.h. for goods locomotives. In order to obtain such a range of speed and evaporation rate, it is insufficient to vary the loading of the train; at least two suitable stretches of grade must be found, one of much less severe grading than the other.

The first step in preparing from the test results the characteristic performance curves of tractive effort at the rims of the driving wheels in terms of rate of evaporation and speed [$F = \Phi \ (z, V)$] is to construct curves of steam consumption on a basis of speed for the various cut-offs, with full regulator opening (fig. 15). A particular rate of evaporation is then selected and the corresponding steam consumption curve drawn (shown as a dotted line, fig. 15). To determine this curve correctly it is necessary to know what proportion of the total steam evaporated is used in auxiliary services. This must be measured during the tests. The dotted curve will cut each steam consumption curve at the speed at which the selected rate of evaporation is attained at the corresponding cut-off.

([53]) Runs at 75 m.p.h. were, however, made with several locomotives.

The curves of tractive effort at the rims of the driving wheels on a basis of speed are then constructed for each cut-off and at full regulator opening (fig. 16).

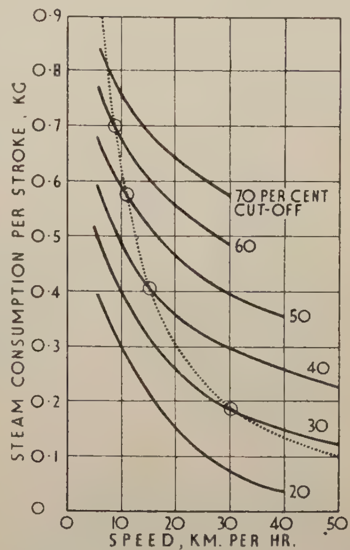


Fig. 15. — Steam consumption curves (Lomonossoff).

On these curves are now marked points corresponding to the speeds at which the selected rate of evaporation is attained as determined by means of figure 15. These curves are joined by means of a new curve which constitutes the characteristic tractive force curve for the locomotive *at that rate of evaporation.* The process is repeated for various rates of evaporation, and so the completed characteristic performance diagram is obtained. Figure 17 shows such a diagram for a 4-6-0 locomotive tested by Professor Lomonossoff. The horizontal position of the upper limiting curve is, of course, the adhesion limit; the sloping portion is part of the tractive effort curve at maximum cut-off, since it is self-evident that the locomotive cannot attain a greater tractive force at a given speed than it exerts at the maximum cut-off which the valve gear per-

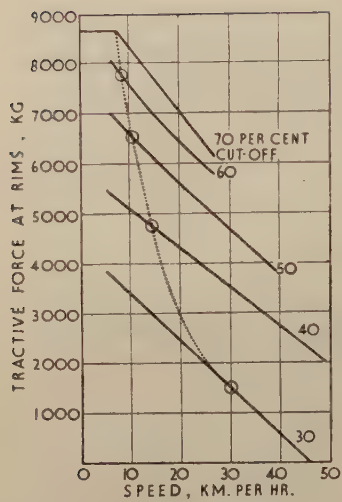


Fig. 16. — Tractive effort curves (Lomonossoff).

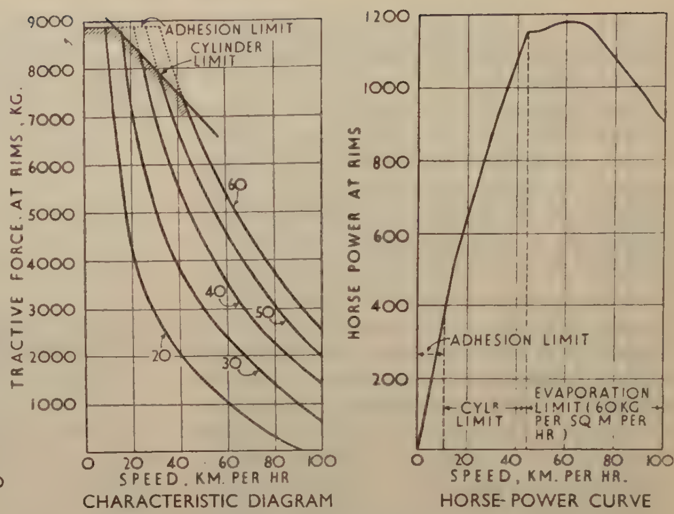


Fig. 17. — Characteristic performance curves (Lomonossoff).

mits and with full regulator opening. This portion of the limiting tractive effort curve varies considerably in prominence for the various locomotives tested by Professor Lomonossoff and it is an interesting factor in design. In some cases it lies entirely outside the adhesion and maximum evaporation curves; in others it is the limiting condition over a speed range from 5 to 55 km. per hour. Its incidence depends largely on the ratio between cylinder size and heating surface, but the fact that it is so important in some cases shows that Goss's asumption that the rate of evaporation at maximum power is constant at all speeds outside the adhesion range, is generally inadmissible.

Polish method (Czeczott). — Professor A. Czeczott was assistant to Professor Lomonossoff from 1910 to 1917 and was appointed Chief Engineer of the Testing Department of the Polish State Railways in 1921. He then evolved a routine method of locomotive testing which differed essentially from the Russian method. Already in 1908 Professor Lomonossoff had made experiments with the use of an auxiliary locomotive to maintain constant conditions, but had abandoned this method as a result of one or two mishaps involving damage to the dynamometer car. Also, by making independent measurements of locomotive and train resistance, he was able, as has been explained, to dispense with the necessity of attempting to secure absolutely constant testing conditions.

Professor Czeczott, however, carried out his experiments with an auxiliary locomotive and was the first to bring this method to success [54]. The weight of the train is fixed so that when the test locomotive is developing its required power, the auxiliary locomotive has to exert no power, neither accelerative nor retardative, to maintain constant speed. On up gradients the auxiliary locomotive assists the locomotive under test, whilst on down grades the auxiliary locomotive together with a number of wagons, is braked. The route selected for test is

[54] For a brief description of the Polish method of testing, see *Bulletin of the Int. Ry. Congress Assn*, July 1931, p. 575.

fairly level, various conditions of working being obtained by varying the weight of the train.

The results of Professor Czeczott's tests are published in the form of booklets ([55]) for each standard type of locomotive, somewhat similar to the Russian « Passport Books ». Performance characteristics of curves of indicated tractive effort and steam consumption per stroke on bases of speed and cut-off, for full open and one-quarter open regulator. Professor Czeczott has described carefully methods of reducing errors due to inequality of combustion conditions at the beginning and end of each test, and claims to have obtained a high degree of accuracy in boiler tests carried ou in this manner.

Czeczott's method has also been used in France in some most interesting series of tests by the P. L. M. Railway. In one series of tests ([56]) comparison was made between 4-8-2 locomotives with various blast pipe arrangements. In another series ([57]) the Henschel high-pressure 4-8-2 locomotive was tested for comparison with the standard 4-8-2 locomotives of the company and with the German Henschel high-pressure locomotive. Tests were made at 60, 80, 95 and 105 km. per hour (37, 50, 60 an 65 m.p.h.) and at five different cut-offs at each speed. Curves show that the constancy of speed attained was remarkable, despite major changes of gradient during the run.

German method (Nordmann). — Meanwhile in the same year (1921) that Professor Czeczott initiated his experiments a decision was made at a conference of engineers of the German State Railways, at which Professor Lomonossoff was present, to adopt the Russian method of testing. It is worth noting, in view of the present position in this country, that a good deal of opposition to the proposal was manifest at this conference, arising out of the belief that it was not possible to obtain constant conditions on the road, and that in any case the accuracy attainable must be so far short of that possible in stationary plant tests as to make the attempt not worth while.

In 1925 Professor Nordmann followed Professor Czeczott and introduced the use of auxiliary locomotives ([58]), but with the important modification that the locomotives employed for this purpose, known as *Bremslokomotiven* (brake locomotives), are specially fitted so as to be capable of braking the train by running in reverse as a compressor. The necessary modifications are quite small. When the locomotive is running in the forward direction with the valve gear in reverse, air is sucked through the exhaust ports, and compressed in the steam passages and superheater tubes. In order not to suck in ashes from the smokebox a sliding plate valve is arranged to close the blast pipe orifice and at the same time provide an alternative opening to the atmosphere through the side of the smokebox. Hot boiler water is sprayed into the incoming air, the evaporation of which affords the requisite cooling during the subsequent compression. The compression pressure can be controlled by throttle valves which allow the compressed air to escape through suitable damping arrangements into the atmosphere. The main means of controlling the braking force of the locomotive is provided, however, by alteration of the setting of the valve gear.

It is possible in this way for a brake locomotive to exert a resistance up to one-tenth of its adhesive weight. Profes-

([55]) Published in Warsaw in Polish. No translations are available.

([56]) *Revue Générale des Chemins de fer*, 1931, vol. 50, p. 273.

([57]) *Ibid.*, 1932, vol. 51, p. 30.

([58]) The German testing method is fully described in *Glasers Annalen*, 1931, vol. 108, p. 52.

sor Nordmann has found that a tendency to slip, together with lubrication troubles due to excessive compression temperatures, makes it impractical to exceed this figure. It is, however, unnecessary, if more than one brake locomotive be used for the tests at greatest loads, to provide any train other than the dynamometer car and brake locomotive or locomotives. In this way a very flexible and accurate means of keeping the speed constant is provided. The brake locomotive is kept in steam and can be used to accelerate the train quickly to the test speed so as to take the maximum advantage of the available length of track. For long tests at high power the water supply of the locomotive under test must be augmented, and this can be done by means of a pipe from the tender of the brake locomotive passing underneath the dynamometer car, thus rendering the test independent of the location of water troughs, and avoiding inaccuracies of measurement of water consumption due to picking up from such troughs. Steam for auxiliary purposes, such as the provision of hot water to the dynamometer car, can also be supplied by the brake locomotive thus eliminating other sources of inaccaracy in measurement. A typical test train is illustrated in figure 18.

Fig. 18. — German test train comprising dynamometer car and brake locomotives.

Technically this method has thus many advantages. Its only drawback is that it is relatively expensive, since no paying load is hauled. But the cost is less than that involved in stationary plant testing.

The stretch of track on which the German tests are carried out is that from Grunewald to Magdeburg via Potsdam and Burg. The preliminary section is used to warm up the locomotive, the actual test stretch being from Potsdam to Burg, a distance of 57 miles, practically level throughout. Experience has shown that a good driver has no difficulty in maintaining the speed very nearly constant throughout the test run by regulation of the brake locomotive, which is fitted for this purpose with a speed indicator having a specially large dial.

In addition to measurements of efficiency, an essential feature of the German method of testing is the provision

of a standard set of characteristic performance curves for each type of locomotive, such a set of curves being reproduced in figure 19. These curves differ from the Russian curves in that they are drawn for one standard rate of evaporation only, that is the maximum continuous rate which it is considered desirable to maintain in service, taken to be 57 kgr. of steam per sq. metre of heating surface. A number of tests at constant speed are run at different powers and cut-offs, from which, by plotting curves, it is not difficult to determine the cut-off necessary to give the required evaporation rate at this speed. A special « boiler

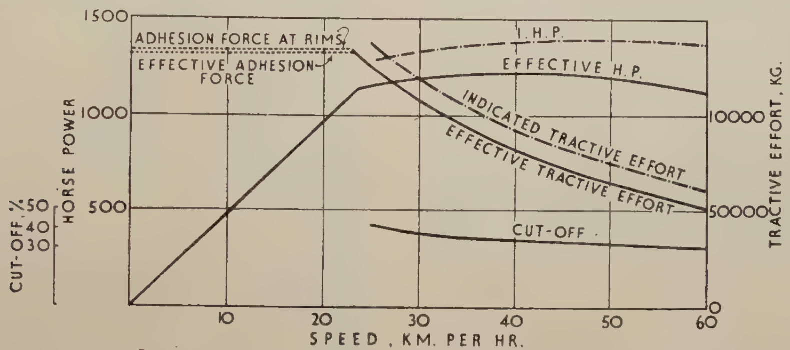


Fig. 19. — Characteristic performance curves (German State Railways)
Rate of evaporation : 57 kgr. per sq. metre per hour.

limit test » at this cut-off and speed is then run, and the process is repeated at a number of other speeds. The characteristic performance curves are constructed directly from the results of the special « boiler limit test ». The points are generally slightly scattered on account of variations of wind resistance and unavoidable slight deviations from the standard evaporation rate. The « effective drawbar pull » and « effective power » are, as has been explained, the equivalent pull and power on a dead level track at constant speed, which since Sanzin's tests has been used as the basis of measurement in Germany.

For the purposes for which such characteristic curves are used, namely fixing train schedules and draughting new designs of locomotives for given duties, it is generally sufficient to choose one rate of evaporation as is done in the German method [59]. Tests at other rates of evaporation, at which of course the locomotive will often work, are of value from the point of view of efficiency rather than power output. This also applies to tests at reduced regulator openings, which are a feature of the Russian method as distinct from the German.

Professor Nordman has maintained that such a set of characteristic performance curves for each main locomotive type, obtained from actual tests at a standard evaporation rate, provide the only satisfactory basis of power rating for locomotives. It has been found as a result of the systematic testing that has now been carried out by the German State Railways that considerable differences in performance may occur between locomotives of similar general dimensions, especially in the upper range of speed which no existing formula

(59) The most economic rate of evaporation, however, varies with the quality of the water and the cost of the fuel.

could take account of. It has even been found that very substantial differences may exist between two locomotives of identical design (60), so that in the ideal it would be desirable to test at least four locomotives of each class. Such a programme has not been carried out, on account of expense, but at least one locomotive of each standard type has been tested and the characteristic performance curves so obtained are now an essential factor in the economical operation of trains. The recent systematic acceleration of German train schedules has been one direct result of this work and the proposals for future improvements can only be carried out successfully if the work of testing is continued and extended still further into the high speed range.

VII. — CONCLUSION.

Testing. — The present position. — Although the constant-condition road tests already described are characteristic of European as distinct from American practice, there are a number of stationary testing plants in Europe, including the most up-to-date in the world, that recently opened at Vitry in France. At the present moment there is a strong division of opinion in European countries between the European and American methods of testing, though it is to be noted that in those countries which have developed scientific methods of road testing, some of which also possess stationary testing plants, the constant-condition road test is favoured for the routine determination of locomotive performance characteristics whilst the stationary plant is regarded as more suited to special tests to establish the value in terms of thermodynamic efficiency, of special devices. Thus the German State Railways possess a modern and well-equipped testing plant at Grunewald, but reserve it chiefly for special tests of this nature. Its routine performance tests are carried out by road trials with brake locomotives, as these are not only found to be perfectly satisfactory, but also give results which may be applied to normal train running conditions with more reliability, and in addition are less expensive than tests on the stationary plant.

On the other hand, the French claim that results of much greater accuracy can be obtained on the new testing plant at Vitry than would be possible under conditions on the track, and, so far as individual measurements are concerned, it is probable that this is true. It is to be remembered, however, that the French have had only a limited experience with constant-condition road tests in the case of one administration only, so that the comparison in this case is possibly intended to apply to road tests under ordinary service conditions, which, as has been seen, are practically valueless for the accurate determination of performance characteristics.

Very recently the Italians have considered the question of what method to adopt and have decided upon constant-effort road tests with a brake locomotive. They claim (61) that such tests, if carried out with a dynamometer car of the most modern type, give results fully equalling in accuracy those obtained on a stationary plant, and more useful than the latter in that they are made under actual running conditions as regards air resistance, and oscillating movements of

(60) Russian tests, however, showed very little variation between locomotives of identical design provided they were in the same condition. For instance, eleven locomotives of the 0-8-0 type were carefully examined and brought to a given standard of condition before testing. The results varied by only 4 % above or below the standard. On the other hand, a 0-10-0 locomotive tested in 1915, and then retested in 1916 after a year's regular service, gave results which varied by 20 %.

(61) *La Tecnica Professionale,* 1934, p. 283.

the locomotive and other tendencies depending on the effect of centrifugal force on curves, or on the action of the spring suspension gear.

It is a questionable point, however, whether the inclusion of wind resistance in measurements based on the « equivalent drawbar pull » should be regarded as an advantage. This, it is true, is the pull available for drawing trains (on the level), but its value is influenced by a factor (the wind resistance) which is only to a partial extent dependent on the design of the locomotive. In tests of the Russian type, based on the tractive effort at the rim of the driving wheels, this factor is eliminated. On the other hand, the proposals for an English stationary testing plant (62) include the provision of a wind tunnel by means of which this factor could, if necessary, be included as a known quantity in test measurements.

The effect of oscillations is only indirect, chiefly by promoting circulation in the boiler. Tests in America have definitively shown that a higher maximum rate of evaporation can be obtained on the track than on the testing plant. The effect on tests at a normal rate of evaporation is probably not very great since a considerable amount of vibration, if not of oscillation, takes place on a testing plant. Professor Lomonossoff has made a direct comparison (63) between constant-condition road tests and stationary plant tests of two 0-10-0 locomotives respectively, of the same type. The road test results were as regular as those obtained on the stationary plant, but tended to show slightly greater indicated powers at the higher speeds. He attributed this to inaccuracies due to the use of a longer indicator pipe in the road tests.

Testing. — The future. — The question as to which is the better method of testing is best decided by reference to the main objective underlying the testing. For the purpose of locomotive research, that is to say the study of individual factors in design and their effect on efficiency, the stationary testing plant undoubtedly offers advantages. For the more general purpose of acquiring systematic data by means of which locomotive power may be used more efficiently and train operation expedited, the experience of those administrations which have developed a routine method of constant-condition road testing for the determination of performance characteristics seems to show that this is the more satisfactory, and certainly much the cheaper, method.

Calculation. — The work of Strahl. — Even constant-condition road tests are expensive to carry out, however, and when sufficient data have been acquired it is not unlikely that further attempts will be made to evolve a satisfactory formula or formulæ by which the power of any new locomotive type may be determined with sufficient accuracy for train operation purposes. Increasing standardisation in design will also help to bring this ideal nearer. It has been made clear that the essential problem is to find some reliable expression for the relationship between speed and mean effective pressure.

The late G. Strahl made a tentative move in this direction in his study « Der Einfluss der Steuerung auf Leistung, Dampf- und Kohlenverbrauch der Heissdampflokomotiven » (The Influence of the Valve-Gear on the Performance and Steam and Coal Consumption of Superheater Steam Locomotives) (64). Proceeding from a geometrical analysis of the indicator diagram he evolved an ex-

(62) *Proc. I. Mech. E.*, 1931, vol. 121, p. 23.

(63) « Lokomotivversuche in Russland », p. 86.

(64) Published by Hanomag-Nachrichten-Verlag G.m.b.H., Hanover-Linden, 1924.

pression for the mean effective pressure in terms of :

(1) Cut-off.

(2) Clearance space.

(3) Steam pressure in the valve chest.

(4) Piston displacement during compression.

(5) Piston displacement during release.

(6) Mean back pressure.

(7) Pressure drop at moment of closing of admission valve.

(8) Exponents of laws of expansion and compression.

Items (6), (7), and (8) require separate estimation. He assumed, because back pressure is generally lower in stationary engines than in locomotives, that the back pressure depends on the sectional area of the blast pipe orifice rather than on the valve gear and is directly proportional to the square of the quantity of steam and inversely proportional to the square of the area of the blast pipe orifice. He gave empirical values for the constant in the relation. The pressure drop during admission depends on the cut-off, speed, cylinder volume, port width, steam lap, lead, clearance space, and quality of the steam. A theoretical analysis of the problem leads to an insoluble differential equation, but by means of an approximation Strahl evolved an expression [65] for the pressure drop in terms of these known quantities and an experimental coefficient for the resistance to flow through the valve opening and port. As regards the exponents of the laws of expansion and compression, he showed the influence of their precise value to be negligible and the use of an average value to be therefore permissible.

Lipetz reports [66] that he attempted to apply Strahl's formula to an American locomotive. It took an experienced calculator two days to obtain three values for the mean effective pressure and these were not in agreement with test results. Strahl himself, however, made it clear that it was not his intention that the formula should be used for the purpose of general calculation of tractive effort. The Prussian State Railways had recently adopted a standard piston valve for superheater locomotives. A two-cylinder and a three-cylinder locomotive having the same total cylinder volume were equipped with the standard piston valves (two and three respectively), but although, as was to be expected, the throttling during admission was found to be greater in the locomotive with only two valves, the effect on steam and fuel consumption appeared to be negligible. This was contrary to the general opinion in Germany at that time regarding the adverse effect of throttling at admission and Strahl wished to analyse quantitatively the factors at play in order to explain why this should be so. He drew a number of curves giving the values for component expressions in his equation for mean effective pressure, as applied to the Prussian State Railways locomotives, in order to facilitate this analysis, and tabulated the results for various speeds. These he found to be in good agreement with indicator diagrams, and therefore to confirm the conclusions based on the experience of the railway.

It is to be observed that Strahl's method of dealing with the back pressure is hardly consistent with the comparatively rigid theoretical treatment of the drop of pressure during admission. The writer's own investigations [67] show that at high speeds, when the phenomenon is of much greater importance since it becomes a limiting factor in the

[65] Strahl's formulæ are not reproduced here. They are of little practical va'ue as yet. All that is intended is to indicate the lines followed by Strahl so that a general idea of this aspect of the subject may be formed.

[66] *Trans. A.S.M.E.*, 1933, vol. 55, RR-55-2.

[67] See *Proc. I. Mech. E.*, 1927, p. 465.

power as well as the efficiency of the locomotive, the effect of the valve gear on back pressure cannot be neglected, and may indeed be the paramount factor in the locomotive's performance.

Difficult though the theoretical estimation of the admission throttling is, a purely theoretical approach to the problem of back pressure, at any rate at high speed, is almost unthinkable, and it is evident therefore that Strahl's work is likely to remain abortive until experimental research of a much more detailed character than has hitherto been contemplated, is undertaken, possibly by means of a locomotive engine unit set up in a laboratory, and supplied with steam from a stationary boiler. Strahl himself made reference to the work of Lihotzky (68), who plotted average curves of mean effective pressure from a large number of indicator diagrams obtained from locomotives of various types, but, as he remarked, by taking average valve gear proportions as a basis, Lihotzky left the question of the influence of the valve gear more or less untouched.

Acknowledgment. — The writer wishes to acknowledge the information and guidance kindly given to him by Professor Dr. Ing. G. V. Lomonossoff.

* * *

We wish to thank *The Railway Gazette* for their kind authority to reproduce the interesting diagrams contained in the present article.

(68) *Z. des österr. Ing. und Arch. Vereins*, 1915, vol. 26.

[621. 43 (.43)]

Latest 100 m. p. h. German trains.

Three-coach units with two supercharged oil engines of 1 200 B. H. P. and hydraulic transmission.

(From *The Oil Fngine.*)

Fig. 1. — One of the latest 100 m.p.h. three-car trains being built for the main lines of the German State Railways.

In the June, 1935, issue of *The Oil Engine* an exclusive account was given of the new two-coach German express railcar trains capable of speeds of 100 m.p.h. now being utilized on some of the main lines, and averaging 70 m.p.h. between terminal stations.

An important new development has

taken place, of which we are now able to publish particulars. A three-coach design has been brought out and in view of the fact that higher power is naturally necessary for this, the 410 B.H.P. Maybach engines installed in the two-coach trains are supercharged to give 600 B.H.P. each, making a total of 1 200 B.H.P. One engine-room is arranged at each end of the train.

Still more important, however, is the

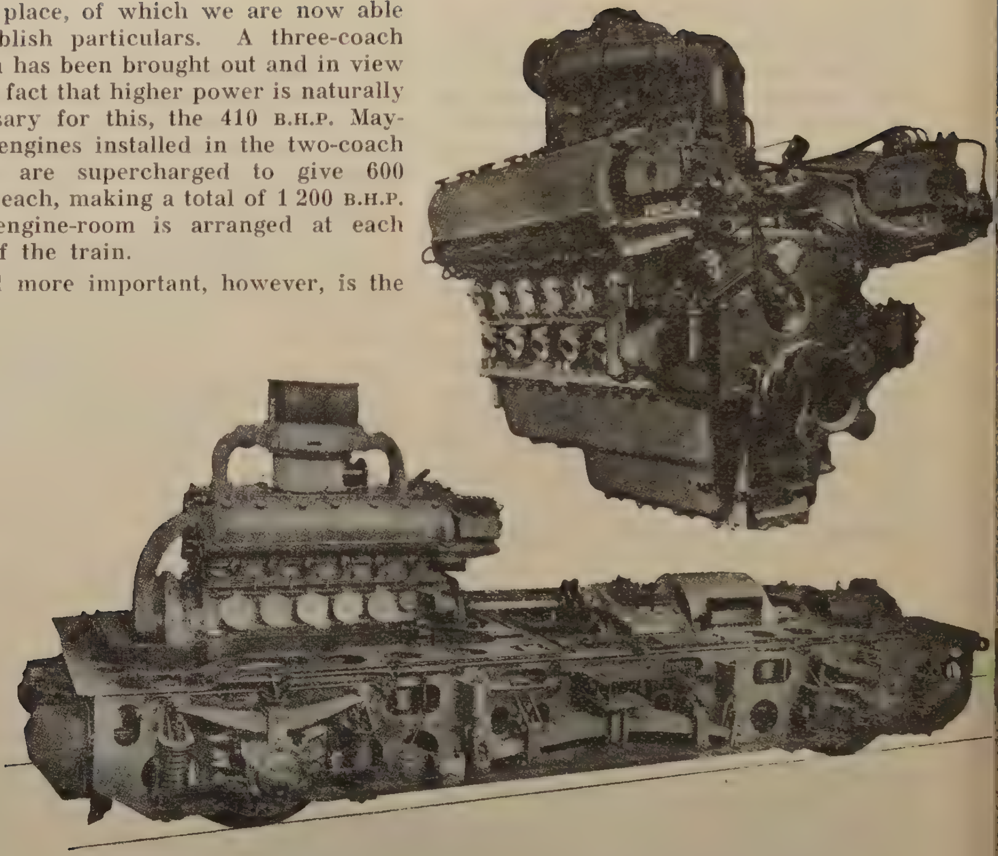


Fig. 2. — One of the complete bogies showing a 600-B.H.P. engine with the hydraulic transmission gear. At the top is a view of the engine showing the supercharger arranged between the cylinders.

employment of hydraulic transmission for the first time in express railcars of this power. Hitherto, electric transmission has been adopted, although in some British railcars of low power mechanical drive has been employed.

One of the reasons for requiring a three-coach train was that on some lines it is necessary to provide for first-class passengers, and, in many instances, the two-coach train has not sufficient accommodation. Compared with the previous two-coach railcar trains, the useful superficial area has been increased by about 50 %. The power is augmented by 50 %, and as the air resistance is only slightly increased and the total weight is not raised in the same proportion as the increased superficial area, the new trains have a higher power reserve than the two-coach units. In order to allow trains to be formed of larger numbers of coaches Scharffenberg automatic couplings are fitted and mul-

tiple control stations can be arranged. In view of the greatly increased driving power, the number of driving axles has been increased by two, so that the relation of driving axles to total number of axles has risen from 2 to 6, to 4 to 8.

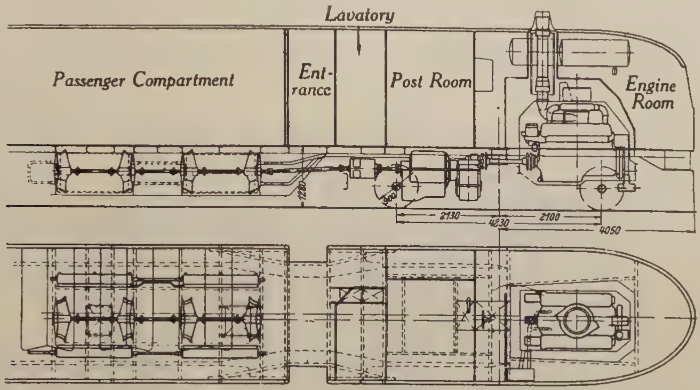


Fig. 3. — Arrangement of the engine and transmission.

The following comparison with the two-coach train is interesting :

	Two-coach diesel-electric trains.	Three-coach diesel hydraulic trains.
Number of passengers	78 (maximum 102).	139 (2nd and 3rd).
Weight, including machinery and fuel .	77 tons.	107 tons.
Fuel capacity	990 litres. (218 gall.).	990 litres. (218 gall.).
Weight of complete engine plant . .	2 070 kgr. (4 563 lb.).	2 450 kgr. (5 400 lb.).

At each end is a Maybach 12-cylinder engine, more or less of the same design as those installed in the « Flying Hamburger » and later railcar units. They are, however, pressure-charged on the Büchi system with Brown-Boveri blowers, and each is designed to develop 600 B.H.P. against the normal output of 410 B.H.P. This rating is for continuous working and the blower driven by exhaust gases from the engine is of the vertical type arranged between the « Vee » of the two groups of cylinders, seen in the illustration. The engine length is therefore not increased.

The air from the blowers is supplied to the inlet valves of the engine at a pressure of about 5 1/2 lb. per sq. inch and the mean effective pressure referred to brake power is between 7.5 and 8.4 atmospheres. The speed is 1 400 r.p.m., and the maximum exhaust gas temperature is not above 500° C. The fuel consumption has improved, and at 600 B.H.P. it is 170 gr. or about 0.38 lb. per B.H.P.-hour, representing some 10 % reduction compared with the unsupercharged engine.

In order to test the relative performances of railcars of this nature with electric and with hydraulic drive respectively, two units with the former system and two with the latter are being built for the German Railways. So far as can be seen, the advantage of the hydraulic system lies in the lower

weight, but it involves the problem of cooling the oil used in the transmission system.

A complete unit of diesel engine, hydraulic drive, gearing and two driving axles, is comprised in one bogie. The motor and the drive are fixed to a special bedplate which is carried with three-point suspension in the bogie frame. It is, however, necessary to arrange between the diesel engine and the primary shaft of the hydraulic gearing a spur wheel transmission, increasing the speed in the ratio of 4 to 3, in order to reduce the dimensions of the gearing.

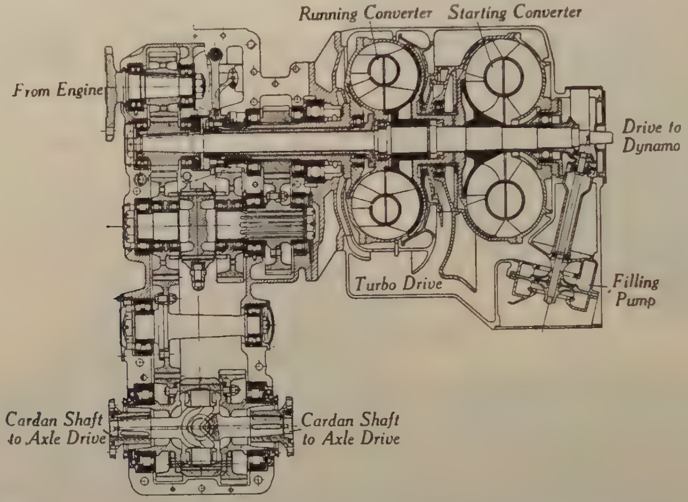


Fig. 4. — The hydraulic mechanical transmission gear from one 600 B.H.P. engine.

The latter is of the Föttinger transformer type with two transformers, which can be alternatively filled or emptied, the control being effected by the driver through electromagnetic valves. The first transformer is for speeds up to 108 km. (67 miles) per hour, whilst the other comes into operation for speeds up to 160 km. (100 miles) per hour. The mechanical gearing is arranged approximately in the centre of the bogie. This involves the drive of both primary wheels of the transformer being taken through a shaft within the hollow secondary shaft. Either of the two secondary wheels drives the reversing gear, through which the two cardan shafts are driven.

Three braking systems are employed, with the motor-driven vehicles, the first being an automatic Knorr air-pressure brake. This serves for ordinary use. Secondly, there is an electro-magnetic Jores-Müller brake. By operating the two sets of brakes, if the train is running at 100 m.p.h. it can be stopped within a distance of about 800 yards. The third brake is worked by means of oil pressure. It is only used in emergency.

The engines having an output of 600 B.H.P. each require effective cooling media and the large coolers for the circulating water are arranged beneath the passenger accommodation, as shown in one of the illustrations. There are two rows, each with four cooling elements, for cooling the oil. Air is drawn

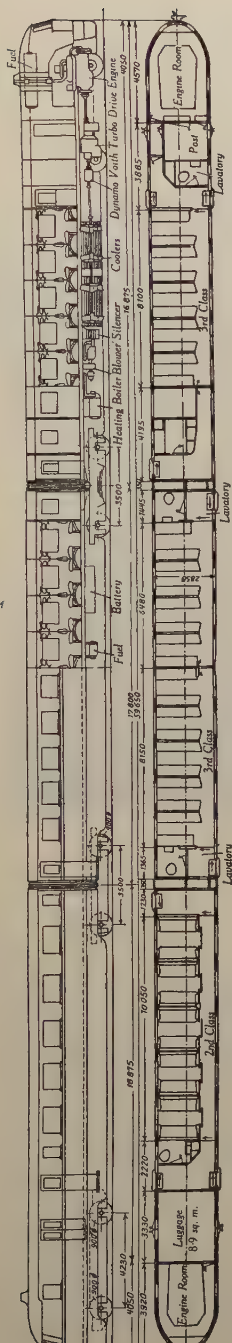


Fig. 5. — Layout of one of the new three-car 100 m.p.h., 1 200 B.H.P. German oil-engined trains with hydraulic transmission.

in through openings at the side of the train and passes over the oil and water coolers, being then discharged by fans driven from an extension of the engine shaft. The inlet temperature of the cooling water is maintained at approximately 50 to 60° C. and distant thermometers record the figure at the driver's stand.

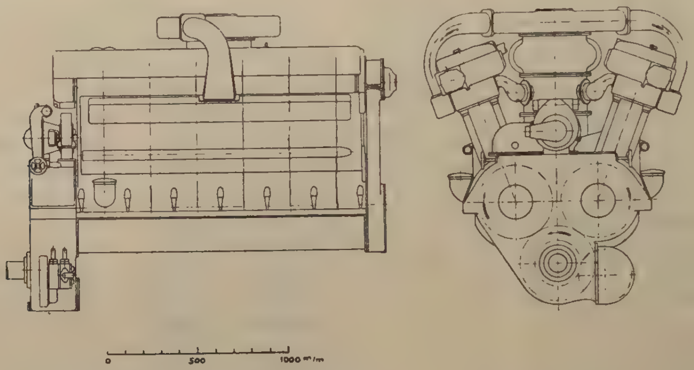
The steel coaches have outside plating 2 mm. to 3 mm. (5/64 to 1/8 inch) in thickness and the axles run in roller bearings. For warming the trains there is a small heating boiler arranged below the floor level of each vehicle. Part of the heat is supplied from the cooling water of the diesel engines in the powers cars, but there is also oil firing, and this is put into operation before the train starts in the morning, so that it is warm. In frosty weather it enables the engine cooling water temperature to be kept well above freezing point at night. Moreover, before starting up, the boiler can be lighted and the cooling water circulating around the engine raised in temperature before the engines are actually run.

The heating of the compartments is effected by means of air. The arrangement employed is to draw in air through openings in the side panels and pass it through a filter in order to eliminate dust. A blower then discharges it over the air heater, whence it passes into the compartments. Part of the air may be drawn in to the compartments without being heated and the temperature is thermostatically controlled. In summer, the heater is completely shut off.

From an extension of the engine shaft a dynamo is driven which supplies current for charging the batteries. The dynamo is arranged to operate as a motor for starting the diesel engine.

M.A.N. engines are also being built for these express trains and illustrations of the latest type are given. Each is designed to develop 560 B.H.P. to 600 B.H.P. at 1 400 r.p.m., and, whilst it has

12 cylinders and is apparently arranged in normal V form, there are two cranks and each group of six cylinders forms a separate engine. It is pressure-charged on the Büchi system, with a Brown-Boveri blower, and on account of the width between the two groups of cylinders driving separate cranks there is ample space for the vertical blower to be located in the manner shown. The overall dimensions of this engine are similar to those of a 400 B.H.P. unsupercharged set, the total length being no more than 1 950 mm., (6 ft. 4 in.), which is remarkably short for an engine developing 600 B.H.P. continuously.



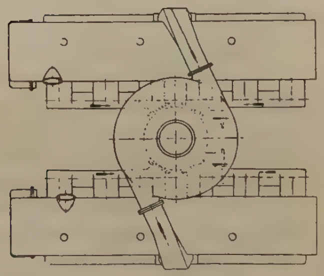


Fig. 6. — Outline plans of a 560-600 B.H.P. M.A.N. engine used in the new German trains.

The manner in which the two engine crankshafts are geared on to the common driving shaft may be noted in the line drawings. The engines have a cylinder diameter of 175 mm. (6 29/32 inches), whilst the piston stroke is 180 mm .(7 5/64 inches).

The four trains of this type are attracting very great interest in Germany not only among railway engineers but also among the travelling public. The present design has only been rendered possible by the application of supercharging to the engines, since in no other way could machinery of necessary power be installed without some distinct modification to the passenger and other arrangements. So far as prolonged tests have been able to show, the supercharged engines should operate with a degree of reliability equal to that of the unsupercharged units. No higher stresses are involved in the mechanism and, owing to the prolongation of the duration of the injection period, the rate of pressure rise is diminished. Moreover, as the inlet valves are opened before the end of the exhaust stroke, a

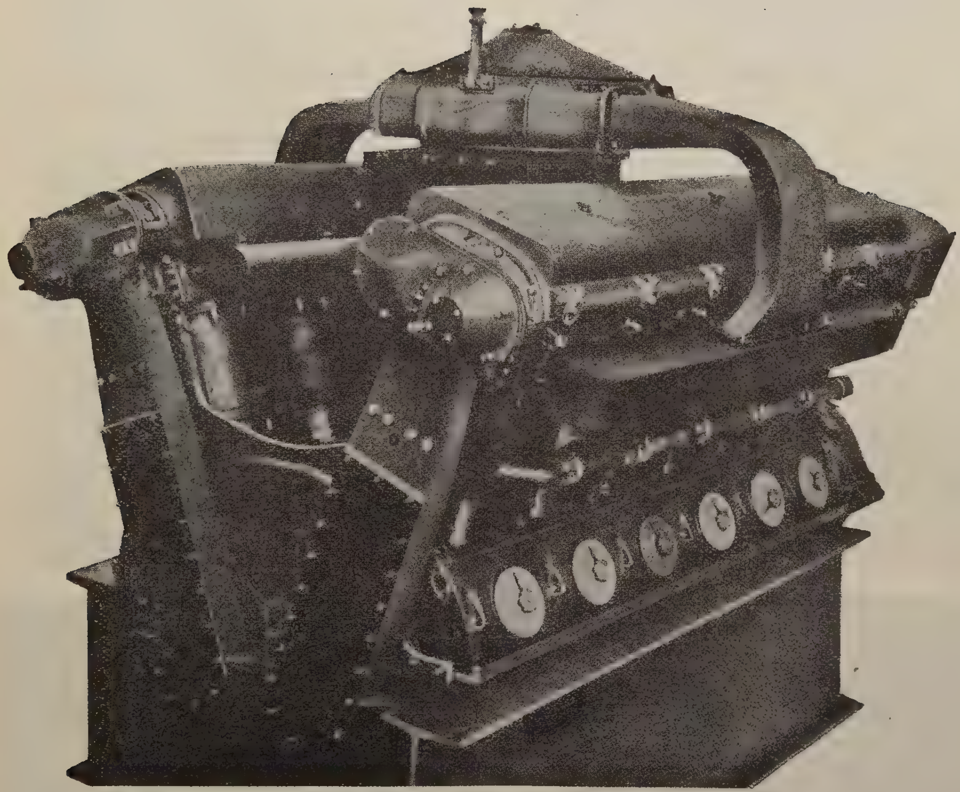


Fig. 7. — 560-600 B.H.P. pressure-charged M.A.N. engine for German express trains. The supercharger is arranged vertically.

scavenging and cooling effect is provided which should tend towards durability in service. The speed of the exhaust-gas-driven blower is 13 000 r.p.m. at normal load, and its input is 56 m^3 (1 977 cu. ft.) of free air per minute. An air filter is arranged on the suction side, and the exhaust-gas turbine is lagged with insulating material. The maximum width is 750 mm. (29 1/2 inches) and the overall height is 782 mm. (30 25/32 inches).

[621. 335 (.436) & 621. 43 (.436)]

Diesel-electric railcars in Austria.

A new high-speed unit,

by Ing. E. KARNER,

Chief Mechanical Engineer. Austrian Federal Railways.

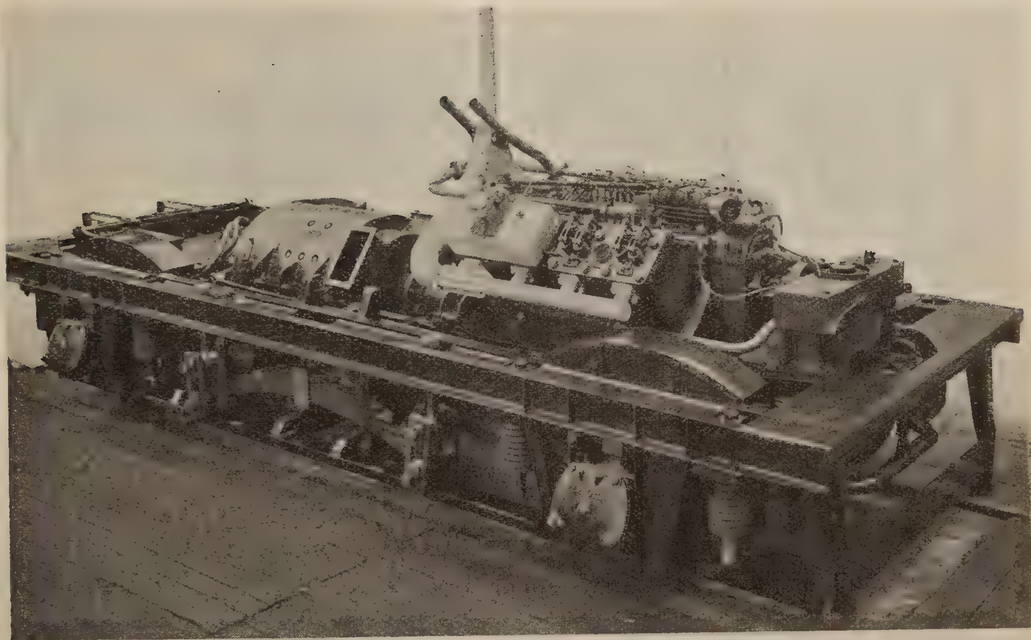
(Modern Transport.)

It is a tendency of modern times to replace the steam locomotive with the railcar, and nowadays practically every railway in the world is, to a greater or less extent, endeavouring to substitute for certain types of long train drawn by a steam locomotive either trains consisting of a railcar with trailers or, in certain circumstances, a railcar alone. The initiation of this tendency was due, primarily, to the competition of road transport, which made it imperative to provide faster and more frequent services, but another incentive was, of course, the paralysis of the economic crisis, which reduced very considerably the number of travellers on the railways, quite apart from those who had gone over to the roads. The net result of all this was that the modern

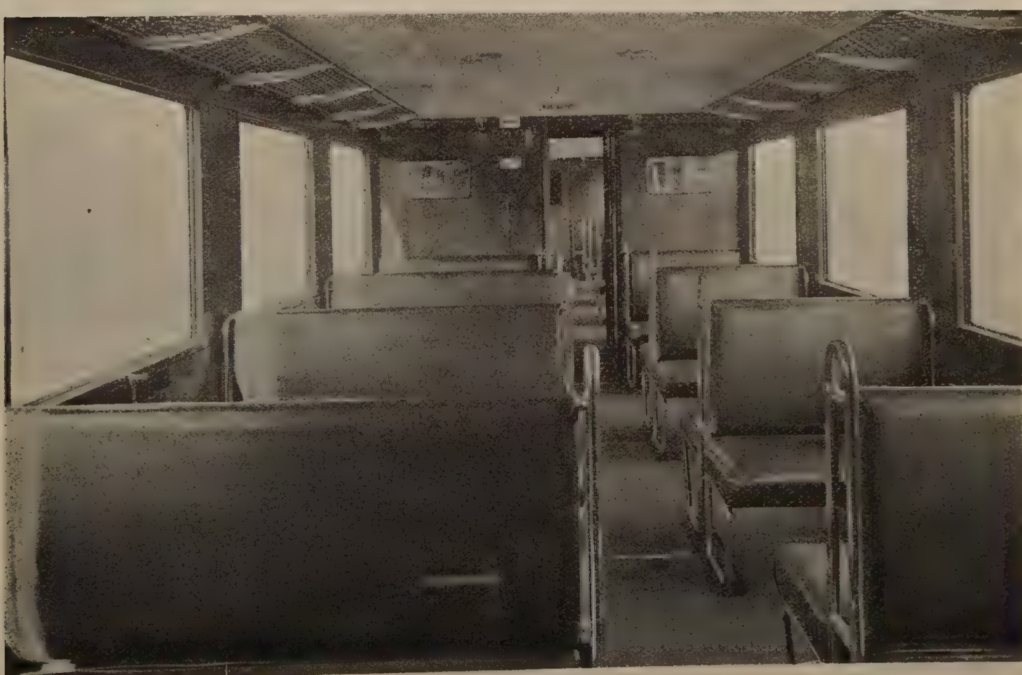
A « V. T. 42 » diesel-electric railcar operated by the Austrian Federal Railways.

railcar engine, and the high-speed diesel engine in particular, was brought to perfection in a remarkably short time, and the railcar itself, due to the intensive study which has been made of its potentialities, compares most advantageously with the older method of working the traffic, inasmuch as only one man is required to drive it; there is a big reduction in the amount of time lost in taking in water, coal, cleaning, greasing, etc., as compared with the steam locomotive; and, furthermore, the motor-driven railcar is ready for the road at a moment's notice.

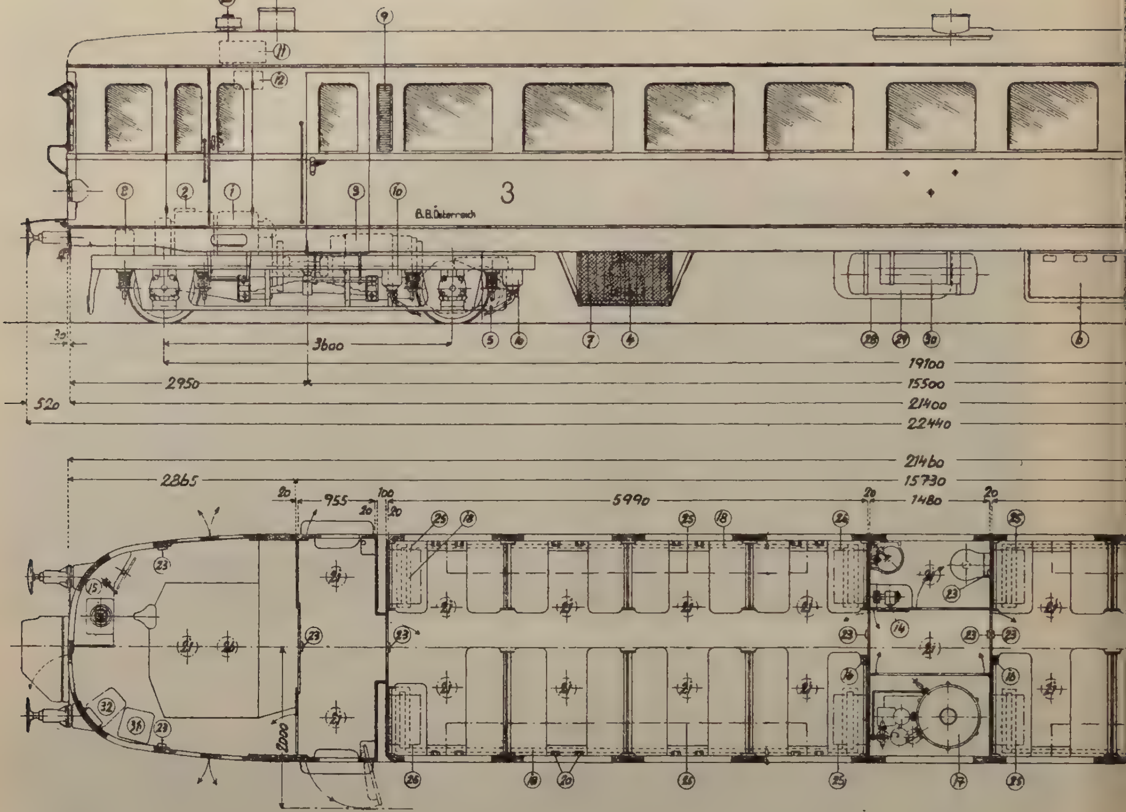
Naturally, the Austrian Federal Railways did not lag behind in this new field of development, but, on the other



The diesel engine, generator and bogie of the « V. T. 42 » railcar.



The non-smoking compartment of the « V. T. 42 » diesel-electric railcar.

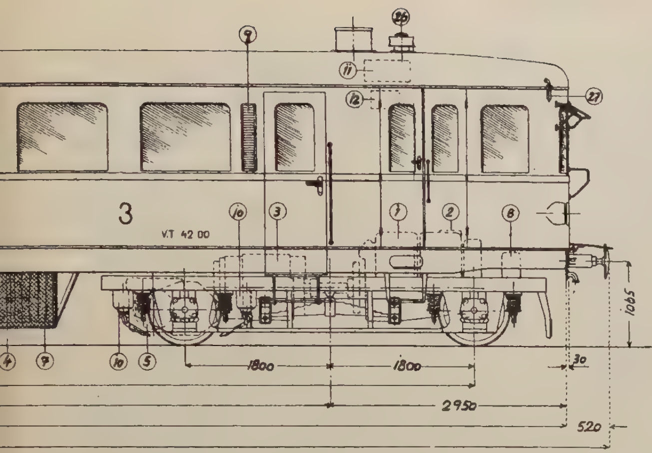


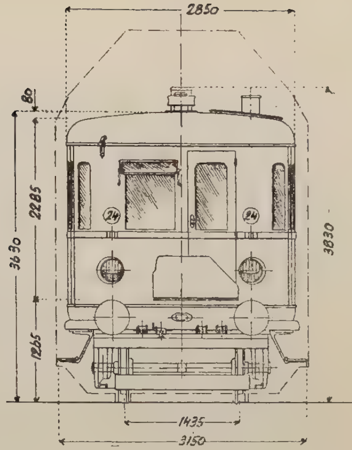
1-Bo-1 diesel-electric railcar, class V T 42, Austrian

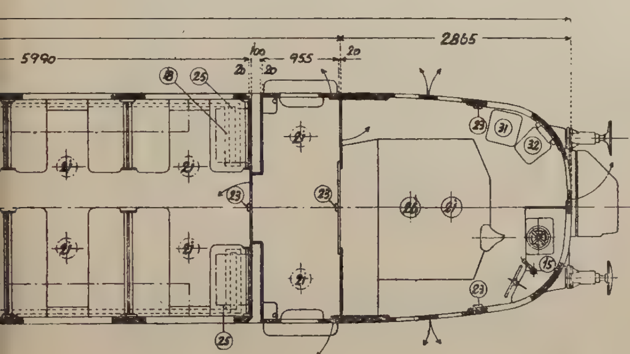
LEGEND.

Mechanical part.

Design : 8-wheeled diesel-electric passenger railcar.	
Rigid wheelbase	...
Total wheelbase	19.100 m. (62 ft. 8 in.).
Overall length	22.440 m. (73 ft. 7 1/2 in.).
Number of driver's compartments	2.
Wheel diameter with 50 mm. (2 in.) tyres	830 mm. (2 ft. 8 5/8 in.).
Weight empty	47 500 kgr. (104 700 lb.).
Weight in service (loaded)	56 500 kgr. (124 500 lb.).
Weight in service (not loaded)	49 200 kgr. (108 500 lb.).
Maximum adhesive weight	29 000 kgr. (63 900 lb.).
Weight per foot of vehicle length	2.51 t./m. (0.75 Engl. t. per ft.).
Maximum speed	110 km. (68.35 miles) p. h.
Draw- and buffing gear	Standard light design.
Kind of brake and percentage of total weight braked	Air brake. 83.2 % — Hand brake. 82.8 %
Sanding gear	Controlled by compressed air, Hardy system.
Type of engine	Diesel with precombustion chamber.
Number of engines	2.
Number of cylinders (cast in pairs)	8.
Bore	150 mm. (5 29/32 in.).
Stroke	190 mm. (7 1/2 in.).
Total power of engine	2 × 210 H. P.
Engine speed (r. p. m.)	1 350.
Volume of cooling water	2 × 200 l. (2 × 44 Br. gall.).
Fuel reserve carried	2 × 250 l. (2 × 55 Br. gall.).
Body — Design	Central corridor.
Compartments	2.
Floor area of luggage compt	2 m² (21.5 sq. feet).
Number of passengers carried	Seated, 78. Standing, none.
Water-closet	1.
Heating	Steam from oil-fired boiler.







Railways.

1. Diesel engine.
2. Compressor.
3. Generator.
4. Cooling ventilator motor.
5. Main electric motor.
6. Battery.
7. Engine cooler.
8. Oil cooler.
9. Air suction for generator.
10. Sanding gear.
11. Oil reservoir.
12. Water tank (engine cooling).
13. Tool chest and accessories.
14. Electric circulating pump.
15. Driver's stand.
16. Emergency brake handle and valve.
17. Steam boiler.
18. Steam heating.
19. Fire extinguisher.
20. Ashpan.
21. Ceiling lamp.
22. Apparatus lamp.
23. Spare lamp rack.
24. Light brackets.
25. Luggage carrier.
26. Ventilator.
27. Whistle.
28. Water tank (steam heating).
29. Main air reservoir.
30. Auxiliary reservoir.
31. Tip-up seat.
32. Folding table.

Electrical part.

Transmission : Electric, « Gebus system ».
Number of steps : Infinite, between 0 and maximum.
Generators. — Driven by articulated coupling with double rubber-lined plates.
Number : 2.
Design : « Elin », self ventilating, type G. A. 125.
Hourly rating : 130 kw., 232 volts, 560 amp., 1 350 r. p. m.
Continuous rating : 130 kw., 325 volts, 400 amp., 1 350 r. p. m.
Maximum speed : 1 400 r. p. m.
Maximum voltage : 440.
Driving motors. — Number : 2.
Design : Brown-Boveri Co., self-ventilating, type G. D. T. M. 2374.
Gear ratio : 1 : 3.53.
Drive : Straight gearing.
Hourly rating : 116 kw. × 230 volts, at 835 r. p. m.
Continuous : 116 kw. × 320 volts, at 1 320 r. p. m.
Maximum speed : 2 570 r. p. m.
Control. — By servo-motor which varies the r. p. m. of the diesel engine.
Starting of diesel : electrically, from generator.
Battery : for lighting and starting purposes.
Number : Four, 12 volts each.
Working voltage : 24 for lighting, 48 for starting.
Capacity : 240 amp./hours, at the 5-hour discharge rate.
Auxiliary generators. — Number : 2.
Design : Self ventilating, with ventilator built in.
Output : 2.5 kw., 48/60 volts, 750 — 1 500 r. p. m.
Continuous tractive effort of railcar :
1 370 kgr. (3 020 lb.) at 59.7 km. (37.1 miles) an hour.
Hourly tractive effort of railcar :
2 160 kgr. (4 760 lb.) at 37.6 km. (23.7 miles) an hour
With 70 mm. (2 3/4 in). thick tyres.
Tractive effort at starting : 5 000 kgr. (11 000 lb.).

hand, they did not allow themselves to be deeply committed to a railcar policy at too early a date; for it was realised that certain technical problems would have to be solved before the railcar could develop its maximum potential efficiency, and, moreover, the reduced demand for traffic facilities meant that the supply of steam locomotives was more than adequate to the existing requirements. Nevertheless, the cult of the railcar was introduced in due time, with results that have proved highly satisfactory.

The latest Austrian railcar.

The most recent development in railcar design, so far as operation on the Austrian Federal Railways is concerned, is that known as series « V. T. 42 », illustrations of which accompany this article. Actually, it is barely ten years since the Austrian Federal Railways first placed orders for railcars in any number, at which time they were destined only for branch line service, and were equipped with engines of low power capable of a maximum speed of 50 km. (31 miles) per hour. At that time, moreover, petrol engines were employed, the high-speed diesel railcar engine not yet having been evolved. At the present time the Austrian Federal Railways are building diesel-engined railcars exclusively, as they are undoubtedly safer, more reliable, and less costly to run. A special advantage of the series « V. T. 42 » diesel-electric railcar is that it introduces for the first time a speed of 110 km. (68 miles) per hour on the Austrian Federal Railways, and, owing to its easy running on curves, they can be taken at speeds 10 km. (6.2 miles) per hour higher than was formerly the case with steam-hauled trains. Owing to its powerful construction and high efficiency, the « V. T. 42 » railcar not only serves as a single express traffic unit, but is also capable of hauling, on a level track, two normal four-axled express passenger coaches, whilst on mountain routes, with a gradient up to 1 in 40, it can haul one trailer of similar type and still adhere to the fastest express schedule. The railcar can be driven from either end, the driving compartment, controls and engine thus being duplicated.

Power installation.

Each of the two bogies of the « V. T. 42 » railcar is provided with an eight-cylinder « V » type diesel engine manufactured by the Simmeringer Maschinen- und Wagonfabriks, A. G., these being directly connected by means of a flexible coupling to an electric generator, and the normal output of each being 210 H.P. at 1 350 r.p.m. The engines are of robust construction and are supported at three double-points in each bogie, whilst the cylinders and housing are of cast-iron, the driving gear being of special steel, and the pistons of light metal. A specially designed pre-combustion chamber, working with Bosch jets and pumps, provides the ignition system, and a triple-pump set assures efficient lubrication, there being also an adequate supply of filters and coolers. The radiators for the engine cooling water are arranged under the railcar body. The ventilating motor (8.5 H.P.) drives not only the fan, but also the lighting system dynamo, and, although these sets are fitted in duplicate, there is only one lighting-system dynamo in circuit at any one time, and that is self-regulating. The starting of the diesel engine is effected by running the generator, which is coupled direct to it, as an electric motor for the time being, the current being supplied by the accumulator battery.

Power is transmitted by means of the « Gebus » system, the output of the diesel engine being conducted to the driving axles of the railcar in such a manner that it remains practically constant

whatever the tractive effort required, and without attention from the driver. Thus, as the tractive effort increases, a variation in speed consistent with the maintenance of the output of the engine is introduced automatically. The « Gebus » generator, which is regulated automatically, conveys the necessary current to the traction motors which, in turn, transmit their power through the medium of reduction wheel gearing, one motor driving one axle of the bogie. The output of the power generator is governed by the speed of the diesel engine, which is regulated by means of a control wheel on the driver's platform, this serving also to put the engine into reverse when required. The railcar is equipped with the Hardy compressed-air brake.

An automatic oil burner on the « V. T. 42 » is capable of raising the steam necessary for heating, in addition to its own passenger compartments, two standard four-axled trailer cars. The car has one smoking and one non-smoking compartment, accommodation being provided for seventy-eight passengers on leather-upholstered seats. There are two entrance doors on each side of the railcar, one at either end, whilst adjoining each driving compartment is a space for luggage. A lavatory and a boiler compartment are arranged centrally in the railcar. The body of the railcar is of steel and is, for the most part, of welded construction. A deadman's handle is incorporated in the safety devices. The maximum speed is 68 m.p.h. when travelling as a single unit and 62 m.p.h. when hauling a trailer coach accommodating 150 passengers.

[313 : 625. 143. 3]

Statistics of rail breakages for the combined years 1933 and 1934.

(*Concluded*).

We publish hereafter, in the form adopted at the Madrid Congress (1930) [1], the information supplied by member Administrations in connection with the rail fractures which occurred on their lines during the combined years 1933 and 1934.

The first part of these statistics appeared in the December 1935 number of the *Bulletin*, pp. 1455 to 1486, and the second part in the January 1936 number, pp. 73 to 107.

In the tables hereafter, and unless stated otherwise [2] :

Light rails *applies to rails of a weight less than 85 lb. per yard (42.5 kgr. per metre),*

Medium rails, *to rails of 85 to 105 lb. per yard (42.5 to 52.5 kgr. per metre),*

Heavy rails, *to those weighing 106 lb. per yard (53 kgr. per metre) or over.*

* * *

No rail breakages were reported in 1933-1934 on the lines of the following Companies :

BELGIUM :

Chimay Railway.

GREECE :

North Western Railway of Greece.

Number of	train-miles . . .	149 130.
	Engl. ton-miles . .	1 367 063.

PORTUGAL :

Companhia Portuguesa para a Construção e Exploração de Caminhos de ferro, Linas do Vale do Vouga.

SWITZERLAND :

Yverdon-Ste-Croix Railway.

Number of	train-miles . . .	98 875.
	Engl. ton-miles . .	4 244 284.

Chemin de fer de Lausanne à Ouchy et des Eaux de Bret.

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(1) See *Bulletin of the Railway Congress*, December 1930, pp. 2236, 2240-2242.
(2) See *Bulletin of the Railway Congress*, March 1926, p. 240.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
HUNGARY. Royal Hungarian State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . .	...	3 637.6	...	1	3 637.6	0.17	2	3 637.6	0.34	1	3 637.6	0.17	429	3 637.6	73.28	433	3 637.6	74.65	9.8-15.7
Medium .	...	1 660.9	...	7	1 660.9	2.62	2	1 660.9	0.75	6	1 660.9	2.24	31	660.9	11.69	46	1 660.9	17.21	15.7-19.7
Total . . .	...	5 298.5	...	8	5 298.5	0.94	4	5 298.5	0.47	7	5 98.5	0.82	460	5 298.5	53.94	479	5 298.5	56.17	

Number of { train-miles : 48 403 500. English ton-miles : 11 530 036 600.

Number of fractures { total : 479. per 10 000 000 tr.-km. or 6 250 000 train-miles : 61.40. per 1 billion tkm. or 612 000 000 English ton-miles : 25.41.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . .	19.6	80.4	273	71	89	421	12
Medium rails .	56.2	43.8	46	...	...	46	...
		Total . .	319	71	89	467	12
			4 546.6	751.9		5 112.1	186.4

		Light rails.	*Medium rails.*
E. *a)* New clean fractures	with internal transverse fissure	117	2
	without internal transverse fissure	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	243	7
	in the head	45	11
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	28	26
d) Number of pieces rails are broken into		2	2

Names of administrations and description of rails.	Age of rails: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
IRISH FREE STATE. Great Southern Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*	...	...	...	...	...	...	...	...	...	...	...	...	21	...	...	21	...	...	16
Medium	...	...	...	...	...	...	1	...	...	1	...	...	6	...	...	8	...	...	18.5
Total	...	...	...	...	...	...	1	...	...	1	...	...	27	...	...	29	...	...	
B. Rails in tunnels. *Light*	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Medium	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Total	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
C. The whole of A and B. *Light*	...	...	...	...	...	...	...	...	...	...	...	...	21	...	...	21	...	...	
Medium	...	...	...	...	...	...	1	...	...	1	...	...	6	...	...	8	...	...	
Total	...	...	...	...	...	...	1	...	...	1	...	...	27	...	...	29	...	...	

Number of train-miles : 17 770 869.

Number of fractures: total : 29; per 10 000 000 tr.-km. or 6 250 000 train-miles : 10.19.

	Percentage of fractures in the part covered by the fishplates.	Percentage of fractures in the part clear of the fishplates.	Number of fractures: on straight lines or curves of > 800 m. (40 chains) radius.	Number of fractures on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Number of fractures on curves of ⩽ 800 m. (40 chains) radius: Higher rail.	Number of fractures on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	Number of fractures on a rising or falling gradient: > 10 mm. per m (1 in 100).
D. *Light rails*	17.24	55.17	16	3	2	1	20
Medium rails	6.90	20.69	7	1	...	1	7
		Total	23	4	2	2	27

E.		*Light rails.*	*Medium rails.*
a) New clean fractures	with internal transverse fissure	4	3
	without internal transverse fissure	9	3
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	1	...
	in the head	5	1
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	2	1
d) Number of pieces rails are broken into		...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
JAPAN. Japanese Government Railways. **Year 1932.**		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A Rails outside tunnels. *Light* . .	8	2 293.8	2.2	125	4 229.3	18.4	47	1 555 4	18.8	30	722.0	25.8	59	932.3	39.3	269	9 732.8	17.2	16.43
Medium .	2	701.1	1.8	9	297.2	18.8	2	15.5	80.1	...	...	...	...	...	...	13	1 013.8	8.0	
Total . . .	10	2 994.9	2.1	134	4 526.5	18.4	49	1570.9	19.4	30	722.0	25.8	59	932.3	39.3	282	10 746.6	16.3	
B. Rails in tunnels. *Light* . .	6	103.8	32.5	63	135.7	288.4	26	38.5	419.1	16	12.2	816 0	2	2.8	438.4	113	293.0	239.6	
Medium .	1	30.1	20.6	163	12.8	7 927.6	...	...	...	...	...	...	...	...	...	164	42.9	2 377.2	
Total . . .	7	133.9	32.5	226	148.5	945.7	26	38.5	419.1	16	12.2	816.0	2	2.8	438.4	277	335.9	512.3	
C. The whole of A and B. *Light* . .	14	2 397.6	3.6	188	4 365.0	26.8	73	1 593.9	28.5	46	734.2	38.9	61	935.1	40.5	382	10 025.8	23.7	
Medium .	3	731.2	2.5	172	310.0	344.7	2	15.5	80.1	...	...	...	...	...	...	177	1 056.7	104.1	
Total . . .	17	3 128.8	3.4	360	4 675.0	47.8	75	1 609.4	29.0	46	734.2	38.9	61	935.1	40.5	559	11 082.5	31.3	

Number of { train-miles : 120 437 295. English ton-miles : 41 223 604 500.

Number of fractures { total : 559. per 10 000 000 tr.-km. or 6 250 000 train-miles : 28.8. per 1 billion tkm. or 612 000 000 English ton-miles : 8.5.

	Percentage of fractures in the part: covered by the fishplates.	Percentage of fractures in the part: clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	on curves of ⩽ 800 m. (40 chains) radius: Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	on a rising or falling gradient: > 10 mm. per m. (1 in 100).
D. *Light rails* . .	51.0 %	49.0 %	265	56	61	279	103
Medium rails .	94.9 %	5.1 %	171	2	4	172	5
		Total . . .	436	58	65	451	108
		Miles of single track of each class.	10 606.0	476.5		9 225.1	1 857.4

E. — No data.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Japanese Government Railways. **Years 1933 - 1934.**		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . .	27	2 187.6	7.7	126	4 135.7	18.9	121	2 014.5	37.3	64	744.2	53.4	164	880.9	115.7	502	9 962.9	31.3	
Medium .	7	427.4	10.2	21	629.8	20.7	3	19.4	96.1	...	...	...	...	...	...	31	1 076.6	17.9	
Total . . .	34	2 615.0	8.1	147	4.765.5	19.2	124	2 033.9	37.9	64	744.2	53.4	164	880.9	115.7	533	11 039.5	30.0	16.68
B. Rails in tunnels. *Light* . .	7	120.9	36.0	81	121.8	413.2	67	40.5	1 028.3	42	15.2	1 713.9	1	2.8	219.0	198	301.2	408.4	
Medium .	14	17.4	500.5	48	27.3	1 091.8	...	...	...	...	...	...	...	...	...	62	44.7	861.9	
Total . . .	21	136.3	94.4	129	149.1	537 5	67	40.5	1 028.3	42	15.2	1 713 9	1	2.8	219.0	260	345.9	467.0	
C. The whole of A and B. *Light* .	34	2 308.5	9.2	207	4 257.5	30.2	188	2 055.0	56.8	106	759.4	86.7	165	883.7	116.0	700	10 264.1	42.4	
Medium .	21	444.8	29.3	69	657.1	65.2	3	19.4	96.1	...	...	...	...	..	...	93	1 121.3	51.5	
Total . . .	55	2 753.3	12.4	276	4 914.6	34.9	191	2 074.4	57.2	106	759.4	86.7	165	883.7	116.0	793	11 385.1	43.3	

Number of { train-miles : 262 730 887. / English ton-miles : 97 158 280 200.

Number of fractures { total : 793. / per 10 000 000 tr.-km. or 6 250 000 train-miles : 18.8. / per 1 billion tkm. or 612 000 000 English ton-miles : 5.0.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails.* . .	41.7 %	58.3	483	98	119	521	179
Medium rails . .	88.2 %	11.8	79	9	5	90	3
		Total . . .	562	107	124	611	182
	Miles of single track of each class.		10 808.1	577.3		9 424.9	1 960.5

E. No data.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Chosen Government Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*	6	626.2	6.0	7	466.0	9.3	15	277.6	33.6	21	302.6	43.1	88	1 562.1	35.0	137	3 234.5	26.3	
Medium	...	279.1	...	...	92.6	...	...	39.8	...	...	...	...	...	...	...	...	411.5	...	
Total	6	905.3	4.1	7	558.6	7.8	15	317.4	29.4	21	302.6	43.1	88	1 562.1	35.0	137	3 646.0	23.3	
B. Rails in tunnels. *Light*	...	12.4	...	...	16.0	...	...	16.9	...	1	13.1	47.4	...	12.0	...	1	70.4	8.8	
Medium	...	6.9	...	...	4.6	...	...	2.4	...	...	...	...	...	...	...	...	13.9	...	
Total	...	19.3	...	...	20.6	...	...	19.3	...	1	13.1	47.4	...	12.0	...	1	84.3	7.4	
C. The whole of A and B. *Light*	6	638.6	5.8	7	482.0	9.0	15	294.5	31.7	22	315.7	43.4	88	1 574.1	34.7	138	3 304.9	25.9	
Medium	...	286.0	...	...	97.2	...	...	42.2	...	...	...	...	...	...	...	...	425.4	...	
Total	6	924.6	4.0	7	579.2	7.5	15	336.7	27.7	22	315.7	43.4	88	1 574.1	34.7	138	3 730.3	23.0	

Number of { train-miles : 22 317 225.
English ton-miles : 1 816 029 425.

Number of fractures { total : 138.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 38.4.
per 1 billion tkm. or 612 000 000 English ton-miles : 46.47.

	Number of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails*	32	108	86	31	21	72	66
Medium rails	...	...	...	...	...	...	...
		Total	86	31	21	72	66
		Miles of single track of each class.	2 744.0	986 3		2 236.6	1 493.7

E		*Light rails.*	*Medium rails.*
a) New clean fractures	with internal transverse fissure	16	...
	without internal transverse fissure	8	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	40	...
	in the head	48	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	19	...
d) Number of pieces rails are broken into		...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
LUXEMBURG. Chemin de fer et Minières Prince Henri.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons
A. Rails outside tunnels. *Light*	...	10.9	...	...	27.2	...	1	7.6	...	...	7.3	...	1	30.7	...	2	83.7	...	15.7
Medium	...	8.7	...	...	23.2	...	...	8.6	...	...	3.8	...	...	1.5	...	...	45.8	...	
Total	...	19.6	...	...	50.4	...	1	16.2	...	...	11.1	...	1	32.2	...	2	129.5	..	
B. Rails in tunnels. *Light*	...	0.2	...	...	0.3	...	...	...	...	...	...	...	...	...	...	...	0.5	...	
Medium	..	...	...	...	0.4	...	...	...	...	...	...	...	...	...	...	...	0.4	...	
Total	...	0.2	...	...	0.7	...	...	...	...	...	...	...	...	...	...	...	0.9	...	
C. The whole of A and B. *Light*	...	11.1	...	...	27.5	...	1	7.6	...	...	7.3	...	1	30.7	...	2	84.2	...	
Medium	...	8.7	...	...	23.6	...	...	8.6	...	...	3.8	...	...	1.5	...	...	46.2	...	
Total	...	19 8	...	...	51.1	...	1	16.2	...	...	11.1	...	1	32.2	...	2	130.4	...	

Number of { train-miles : 1 965 262. English ton-miles : 125 094 338.

Number of fractures { total : 2. per 10 000 000 tr.-km. or 6 250 000 train-miles : 6.52. per 1 billion tkm. or 612 000 000 English ton-miles : 9.76.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ≤ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails*	50 %	50 %	1	...	1	2	...
Medium rails	...	...	...	...	...	...	...
		Total	1	...	1	2	...
	Miles of single track of each class.		86.4	44.7		61.5	21.1

		Light rails.	*Medium rails.*
E. — *a*) New clean fractures	with internal transverse fissure	...	...
	without internal transverse fissure	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	...	...
	in the head	2	...
c) Fractures with much rusted old part, *not* extending	in the web		

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
NORWAY. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light.*	No records available.																		
Medium.																			
Total . . .																			
B. Rails in tunnels. *Light.*																			
Medium.																			
Total . . .																			
C. The whole of A and B. *Light.*	15	...	...	8	...	...	23	...	...	28	...	...	19	...	...	93	2 129.5	27	17.7
Medium.	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	74.6	8.3	17.7
Total . . .	16	...	...	8	...	...	23	...	...	28	...	...	19	...	...	94	2 204.1	26.4	

Number of { train-miles : 16 397 040. / English ton-miles : 417 919 478.

Number of fractures { total : 94. / per 10 000 000 tr.-km. or 6 250 000 train-miles : 36. / per 1 billion tkm. or 612 000 000 English ton-miles : 138.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ≤ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100).	> 10 mm. per m (1 in 100).
D. *Light rails* . . .	18 %	82 %	62	17	14	48	45
Medium rails . .	100 %	...	...	1	...	1	...
		Total . . .	62	18	14	49	45
	Miles of single track of each class.		1 458.5	745.6		...	...

E.	*Light rails.*	*Medium rails.*
a) New clean fractures, with internal transverse fissure	...	...
a) New clean fractures, without internal transverse fissure	51	1
b) Fractures with much rusted old part, extending to the outer surface of the boot or the head: in the foot	27	...
in the head	4	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head: in the web	11	...

d) Number of pieces rails are broken into : 1 rail, 3 pieces; all others 2.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
HOLLAND Netherlands Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A Rails outside tunnels. *Light.*	...	238.6	...	17	535.6	20	39	813.4	30	25	390.2	40	176	2 127.6	51	257	4 105.4	39	15.7
A Rails outside tunnels. *Medium.*	...	625.1	...	7	518.2	8	56	629.5	55	14	404.5	22	21	285.2	46	98	2 462.5	25	19.7
Total . . .	...	863.7	...	24	1 053.8	14	95	1442.9	41	39	794.7	31	197	2 412.8	51	355	6 567 9	34	

Number of { train-miles : 67 730 700. / English ton-miles : data not available.

Number of fractures { total : 355. / per 10 000 000 tr.-km. or 6 250 000 train-miles : 33. / per 1 billion tkm or 612 000 000 English ton-miles : ...

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . . .	69 %	31 %	216	10	31	257	...
D. *Medium rails* . .	70 %	30 %	87	5	6	98	...
		Total . . .	303	15	37	355	...
		Miles of single track of each class.	6 544.8	329.1		6 567.9	...

E.		*Light rails.*	*Medium rails.*
a) New clean fractures	with internal transverse fissure . . .	...	...
	without internal transverse fissure . . .	67	28
b) Fractures with much rusted old part, extending to the outer surface of the boot or the head	in the foot . . .	92	17
	in the head . . .	15	5
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web . . .	83	48
d) Number of pieces rails are broken into	2 pieces . . .	204	81
	3 — . . .	42	9
	4 — . . .	11	8

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
DUTCH COLONIES. Dutch Indies State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*(*).	...	18.0	...	2	295.2	4.20	6	274.0	13.56	4	568.6	4.36	49	*1 646.0	18.13	61	2 801.8	13.42	...
B. Rails in tunnels. *Light*(*).	...	...	...	...	...	...	1	0.6	1 000	...	0.6	...	...	2.5	...	1	3.7	166.67	...
C. The whole of A and B. *Light*(*).	...	18.0	...	2	295.2	4.20	7	274.6	15.82	4	569.2	4.36	49	1 648.5	18.13	62	2 805.5	13.64	

Number of { train-miles : 28 873 480. English ton-miles : 569 634 420.

Number of fractures { total : 62. per 10 000 000 tr.-km. or 6 250 000 train-miles : 13.34. per 1 billion tkm. or 612 000 000 English ton-miles : 66.56.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D *Light rails.*	4.8 %	95.2 %	35	13	14	57	5
	Miles of single track of each class.		2 471.1	434.4		2 396.0	409.5

E.		*Light rails.*
a) New clean fractures	with internal transverse fissure	5
	without internal transverse fissure	25
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	31
	in the head	14
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	15
d) Number of pieces rails are broken into	2 pieces	45
	3 pieces	2
	cracked	15

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Dutch Indies Railways Company.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles		English tons.
A. Rails outside tunnels :																			
Light	...	42.2	...	...	10.6	...	...	126.8	...	...	42.9	...	1	320.0	2	1	542.5	1.15	...

Number of { train-miles : 5 462 699. English ton-miles : 156 386 900.

Number of fractures { total : 1. per 10 000 000 tr.-km. or 6 250 000 train-miles 1.14. per 1 billion tkm. or 612 000 000 English ton-miles : 3.91.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails.* .	...	100 %.	...	...	1	...	1

		Light rails.
E. a) New clean fractures	with internal transverse fissure	...
	without internal transverse fissure	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	1
	in the head	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	...
d) Number of pieces rails are broken into		2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
POLAND. **State Railways.**		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light.*	36	695.9	32.1	138	2 144.4	40.0	95	370.3	159.4	214	1 162.0	114.4	1580	9 421.4	104.2	2063	13 194.0	92.9	18.0
Medium.	...	...	...	...	...	...	2	167.8	7.4	11	298.9	22.8	31	276.5	6.9	44	743.2	36.9	
Total . . .	36	695.9	32.1	138	2 144.4	40.0	97	538.1	112.0	225	1 460.9	95.7	1611	9 697.9	103.2	2107	14 537.2	90.0	

Number of { train-miles : 126 733 475.
English ton-miles : 57 413 638 150.

Number of fractures { total : 2 107.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 103.3.
per 1 billion tkm. or 612 000 000 English ton-miles : 22.4.

	Percentage of fractures in the part: covered by the fishplates.	Percentage of fractures in the part: clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	on curves of ⩽ 800 m. (40 chains) radius: Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	on a rising or falling gradient: > 10 mm. per m. (1 in 100).
D. *Light rails* . . .	36 %	64 %	1 682	207	174	398	347
Medium rails . . .	38 %	62 %	39	2	3	11	8
	Total . . .		1 721	209	177	409	355
	Miles of single track of each class.		...	...		8 809.3	828.9

E.		*Light rails.*	*Medium rails.*
a) New clean fractures	with internal transverse fissure	319	1
	without internal transverse fissure	330	4
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	229	2
	in the head	468	14
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	359	12
d) Number of pieces rails are broken into		...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PORTUGAL. Portuguese Railways Company.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . .	...	...	...	...	...	...	...	...	...	...	...	..	1391	1 432.7	603	1391	1 432.7	603	
A. Rails outside tunnels. *Medium* .	...	...	...	...	...	...	...	...	...	...	...	...	11	357.9	19	11	357.9	19	...
Total . . .	...	...	...	...	...	...	...	...	...	...	...	...	14 2	1 790.6	486	1402	1 790.6	486	

Number of { English ton-miles : 15 422 790. / train-miles : 3 208 557 360.

Number of fractures { total : 1 402. / per 10 000 000 tr.-km. or 6 250 000 train-miles : 564.86. / per 1 billion tkm. or 612 000 000 English ton-miles : 267.22.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . .	3.5 %	96.5 %	922	336	133	435	461
D. *Medium rails* .	45.5 %	54.5 %	7	2	2	1	3
		Total . . .	929	338	135	436	464
		Miles of single track of each class.	1 428.2	362.4		717.7	519.5

E.		*Light rails.*	*Medium rails.*
a) New clean fractures	with internal transverse fissure	24	2
	without internal transverse fissure	1 367	9
b) Fractures with much rusted old part, extending to the outer surface of the boot or the head	in the foot	423	2
	in the head	547	5
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	243	2
d) Number of pieces rails are broken into		2/3	2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Portuguese National Railways Company.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . .	1	7.5	83	...	...	...	...	...	...	...	...	...	118	181.4	404	119	188.9	391	10.8

Number of { train-miles . 694 162. / English ton-miles : 58 569 310.

Number of fractures { total : 119. / per 10 000 000 tr.-km. or 6 250 000 train-miles : 1 065. / per 1 billion tkm. or 612 000 000 ton-miles : 1 242.

	Percentage of fractures in the part: covered by the fishplates.	Percentage of fractures in the part: clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	on curves of ⩽ 800 m. (40 chains) radius: Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	on a rising or falling gradient: > 10 mm. per m. (1 in 100).
D. *Light rails.* . .	...	100 %	29	68	22	83	36

		Light rails.
E. *a*) New clean fractures	with internal transverse fissure	53
	without internal transverse fissure	65
b) Fractures with much rusted old part, extending to the outer surface of the boot or the head	in the foot	..
	in the head	..
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	1
d) Number of pieces rails are broken into		Generally 2.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Beira Alta Railway.		Miles.			Miles			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . .	...	...	...	...	...	...	...	...	...	...	...	...	52	156.8	206.15	52	156.8	206.15	13.8

Number of { train-miles : 998 462. English ton-miles : 165 994 340.

Number of fractures { total : 52. per 10 000 000 tr.-km. or 6 250 000 train-miles : 323.6. per 1 billion tkm. or 612 000 000 English ton-miles : 206.15.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails.* .	...	100 %	41	5	6	...	...
	Miles of single track of each class.		on curves . . . 68.8 on straight lines . . . 88.0			on gradients . . . 115.2	

	Light rails.
E. *a*) New clean fractures { with internal transverse fissure . . .	No data.
without internal transverse fissure . . .	
b) Fractures with much rusted old part, extending to the outer surface of the boot or the head { in the foot . . .	
in the head . . .	
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the web . . .	
d) Number of pieces rails are broken into . . .	2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PORTUGUESE COLONIES. Benguela Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles		English tons.
A. Rails outside tunnels. { *Light.*	...	...	...	4	837.0	3	1	837.0	1	...	...	...	10	837.0	8	15	837.0	12	12.9

Number of { train-miles : 1 292 764.
English ton-miles : 125 860 355.

Number of fractures { total : 15.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 72.
per 1 billion tkm. or 612 000 000 English ton-miles : 73.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . . .	33 %	67 %	8	5	2	5	10

		Light rails.
E. *a)* New clean fractures	with internal transverse fissure	4
	without internal transverse fissure	2
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	3
	in the head	4
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	2
d) Number of pieces rails are broken into		2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			Maximum axle load.
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
Railways in the Mozambique Colony.																			
A. Rails outside tunnels. } *Light.*	...	133.0	...	...	76.9	...	3	49.4	37.7	27	206.1	81	26	96.9	166.6		562.3	285.3	15.3

Number of { train-miles : 1 151 185. / English ton-miles : 343 970 400.

Number of fractures { total : 56. / per 10 000 000 tr.-km. or 6 250 000 train-miles : 302.4. / per 1 billion tkm. or 612 000 000 English ton-miles : 99.5.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails.*	...	100 %.	16	...	40	20	36
	Miles of single track of each class.		504.6	57.7		407.1	155.2

		Light rails.
E. *a*) New clean fractures	with internal transverse fissure	2
	without internal transverse fissure	1
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	4
	in the head	48
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	...
d) Number of pieces rails are broken into		2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Maximum axle load.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
RUMANIA. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light.*	4	9.3	266	5	12.4	250	1	7.5	92	12	9.3	790	1832	8 537.6	135	1854	8 537.6	137	
Medium.	24	136.7	109	26	671.7	24	1	375.3	1.5	...	...	...	...	...	...	51	1 188.7	26.6	
Total . . .	28	146.0	119	31	684.1	28	2	382.8	3.2	12	9.3	790	1832	8 537.6	135	1905	9 546.3	124	
B. Rails in tunnels. *Light.*	...	...	...	...	...	...	...	...	...	...	...	..	...	23.0	...	..	23.0	...	
Medium.	8	5.0	1 000	...	...	...	...	...	...	...	...	...	...	...	...	8	5.0	1 000	
Total . . .	8	5.0	1 000	...	...	...	...	...	...	...	...	...	...	23.0	...	8	28.0	178	
C. The whole of A and B *Light*	4	9.3	266	5	12.4	250	1	7.5	92	12	9.3	790	1832	8 560.6	136	1854	8 560.6	137	
Medium.	32	141.7	140.3	26	671.7	24	1	375.3	1.5	...	...	...	...	...	...	59	1 193.7	30.7	
Total . .	36	151.0	148.1	31	684.1	28	2	382.8	3.2	12	9.3	790	1832	8 560.6	136	1913	9 754.3	124	

Number of { train-miles : 65 250 000. English ton-miles : 21 062 412 250.

Number of fractures { total : 1 913. per 10 000 000 tr.-km. or 6 250 000 train-miles : 182.18. per 1 billion tkm. or 612 000 000 English ton-miles : 55.5.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . .	34.5 %	65.5 %	1 636	218	...	1 676	178
Medium rails .	13.5 %	86.5 %	47	...	12	15	44
		Total . . .	1 683	218	12	1 691	222
	Miles of single track of each class.		7 568.4	2 185.9		8 348.7	1 405.6

E.		*Light rails.*	*Medium rails.*
a) New clean fractures	with internal transverse fissure . . .	228	59
	without internal transverse fissure . . .	508	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot . . .	824	...
	in the head . . .	228	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web . . .	66	...
d) Number of pieces rails are broken into . . .		3 in 12 cases.	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
SWEDEN.																			
State Railways.																			
C Rails outside and in tunnels. *Light*	19	...	...	43	...	...	17	...	...	22	...	...	317	...	...	418	4 176.3	62	17.2
C Rails outside and in tunnels. *Medium*	2	...	...	20	...	...	...	...	...	...	...	...	...	...	...	22	714.6	19	17.2
Total . . .	21	...	...	63	...	...	17	...	...	22	...	...	317	...	...	440	4 890.9	56	

Number of { train-miles : 47 197 470.
English ton-miles : 2 190 348 165.

Number of fractures { total : 440.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 58.
per 1 billion tkm. or 612 000 000 English ton-miles : 123.

		Light rails.	*Medium rails.*
E. *a)* New clean fractures	with internal transverse fissure	...	...
	without internal transverse fissure	...	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	63	7
	in the head	...	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	...	...
d) Number of pieces rails are broken into		...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nora-Bergslagen Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light* . .	...	...	...	...	...	...	...	...	...	...	...	...	1	108.25	5.78	1	108.125	5.78	13.79

Number of { train-miles : 384 325.
English ton-miles : 21 741 250.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ≤ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . .	...	100 %	...	1	...	...	1
	Miles of single track of each class.		75.5	61.2		76.225	31.9

		Light rails.
E. *a)* New clean fractures	with internal transverse fissure	...
	without internal transverse fissure	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	1
	in the head	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	...
d) Number of pieces rails are broken into		2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Norra-Östergötland Railway. (*)		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light.*	...	...	...	...	...	...	...	11.2	...	...	...	...	29	71.5	251	29	82.7	218	4.9

Number of { train-miles : 623 246. English ton-miles : 67 089 050.

Number of fractures { total : 29. per 10 000 000 tr.-km. or 6 250 000 train-miles : 290. per 1 billion tkm. or 612 000 000 English ton-miles : 265.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100)	> 10 mm. per m. (1 in 100).
D. *Light rails* . . .	72 %	28 %	18	11	...	7	7
	Miles of single track of each class.		52.9	29.8		51.0	

	Light rails.
E. *a*) New clean fractures { with internal transverse fissure . . .	...
without internal transverse fissure . . .	5
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot . . .	4
in the head . . .	2
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the web . . .	18
d) Number of pieces rails are broken into . . .	2 rails 3 pieces; others 2.

(*) This Company points out that the large number of fractures reported is abnormal and that the track has been strengthened by the use of heavier rails.

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Stockholm-Västeras-Bergslagen Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside unnels :																			
Light	...	...	...	...	...	...	...	...	...	...	...	...	2	...	4.1	2	...	4.1	6.4

Number of { trains-miles : 2 765 670. English ton-miles : 46 308 155.

Number of fractures { total : 2. per 10 000 000 tr.-km. or 6 250 000 train-miles : 4.4.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . . .	50 %	50 %	2	...	...	2	...
	Miles of single track of each class.		247.3	50.3		287.7	9.9

		Light rails.
E. *a*) New clean fractures	with internal transverse fissure	...
	without internal transverse fissure	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	2
	in the head	...
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	...
d) Number of pieces rails are broken into		2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Grängesberg-Oxelösund Railway Company.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels; *Light*	...	...	...	...	...	...	...	...	...	...	...	...	10	208.8	29.76	10	208.8	29.76	17.7

Number of { train-miles : 2 112 987. English ton-miles : 380 749 952.

Number of fractures { total : 10. per 10 000 000 tr.-km. or 6 250 000 train-miles : 29.4. per 1 billion tkm. or 612 000 000 English ton-miles : 16.06.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails* . . .	30 %	70 %	6	1	3	10	...
	Miles of single track of each class.		177.1	51 7		187.7	21.1

		Light rails.
E. *a*) New clean fractures	with internal transverse fissure	...
	without internal transverse fissure	7
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	...
	in the head	2
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head . . .	in the web	1
d) Number of pieces rails are broken into		2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
Note: The figures in columns 3 and 6 are rough estimates.																			
1	2	3	4	5	6	7	8	9	10	11	12	13	4	15	16	17	18	19	20
SWITZERLAND. Federal Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light.*	...	36.0	...	...	78.9	...	1	...	...	1	...	...	56	...	...	58	466.7	77.2	
Medium.	12	1 040 2	7.2	37	762.4	30.2	17	...	...	20	...	...	127	...	...	213	1 872.8	70.7	
Total . . .	12	1 076.2	6.9	37	841.3	27.3	18	...	...	21	...	...	183	...	...	271	2 339.5	72.1	
B. Rails in tunnels. *Light.*	...	...	...	...	...	...	...	...	...	...	...	...	4	...	...	4	4.4	571.4	
Medium	...	59.0	...	7	69.0	63.1	9	...	...	13	...	...	11	...	...	40	136.7	181.8	
Total . . .	...	59.0	..	7	69.0	63.1	9	...	...	13	...	...	15	...	...	44	141.1	193.8	
C. The whole of A and B. *Light.*	...	36.0	...	...	78.9	...	1	...	...	1	...	...	60	...	...	62	471.1	81.8	
Medium.	12	1 099.2	6.8	44	831 4	32 9	26	...	...	33	...	...	138	...	...	253	2 009.5	78 2	
Total . . .	12	1 135.2	6.6	44	910.3	30.0	27	...	...	34	...	...	198	...	...	315	2 480.6	78.9	

Number of { train-miles : 49 658 410. English ton-miles : 1 985 794 500.

Number of fractures { total : 315. per 10 000 000 tr.-km. or 6 250 000 train-miles : 39.4. per 1 billion tkm. or 612 000 000 English ton-miles : 97.0.

	Percentage of fractures in the part		NUMBER OF FRACTURES:				
	covered by the fishplates.	clear of the fishplates.	on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	on curves of ⩽ 800 m. (40 chains) radius: Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	on a rising or falling gradient: > 10 mm. per m. (1 in 100).
D *Light rails* . .	16.8	2.9	36	14	12	40	22
Medium rails .	55.2	25.1	177	50	25	203	50
		Total . . .	213	64	38	243	72

	Light rails.	*Medium rails.*
E. *a*) New clean fractures { with internal transverse fissure . . .	...	1
without internal transverse fissure . . .	10	41
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head { in the foot . . .	8	34
in the head . . .	5	20
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head { in the web . . .	35	136
d) Number of pieces rails are broken into . . .	...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Berne-Lötschberg Simplon Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*	...	1.5	...	...	...	...	...	...	...	...	...	...	2	56.6	21	2	58.1	21	
Medium	...	...	...	1	0.6	980	3	1.8	1 060	9	12.3	454	...	...	...	13	14.7	549	
Total . . .	...	1.5	...	1	0.6	980	3	1.8	1 060	9	12.3	454	2	56.6	21	15	72.8	128	
B. Rails in tunnels. *Light*	...	...	...	...	5.2	...	1	1.6	380	...	...	...	15	23.9	390	16	30.7	424	
Medium	...	3.7	...	10	5.1	1 219	...	...	...	...	0.2	...	...	...	...	10	9.0	684	19.7
Total . . .	...	3.7	...	10	10.3	604	1	1.6	380	...	0.2	...	15	23.9	390	26	39.7	406	
C. The whole of A and B. *Light*	...	1.5	...	...	5.2	...	1	1.6	380	...	...	...	17	56.6	131	18	88.8	126	
Medium	...	3 7	...	10	5.7	1 085	3	1.8	1 060	9	12.5	445	...	23.9	...	23	23.7	601	
Total . . .	...	5.2	...	10	10.9	569	4	3.4	751	9	12.5	445	17	80.5	131	41	112.5	226	

Number of { train-miles : 2 178 220. English ton-miles : 611 191 305.

Number of fractures { total : 41. per 10 000 000 tr.-km. or 6 250 000 train-miles : 119. per 1 billion tkm. or 612 000 000 English ton-miles : 41.

	Number of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 1 000 m. (50 chains) radius.	on curves of ⩽ 1 000 m. (50 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails*	14	4	13	1	4	12	6
Medium rails	18	5	17	3	3	13	10
		Total . . .	30	4	7	25	16
	Miles of single track of each class.		68.4	31.0		49.1	50.3

		Light rails.	*Medium rails.*
E. *a)* New clean fractures	with internal transverse fissure	5	3
	without internal transverse fissure		
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	5	15
	in the head	...	
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	8	5
d) Number of pieces rails are broken into		2 and 3	2

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rhaetian Railway.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*	...	...	...	...	...	...	...	...	...	1	...	...	7	...	...	8	...	...	10.8
B. Rails in tunnels. *Light*	...	...	...	1	...	...	...	...	...	...	...	...	2	...	...	3	...	...	10.8
C. The whole of A and B. *Light*	...	...	...	1	...	...	...	...	...	1	...	...	9	...	...	11	277	39	...

Number of { train-miles : 2 191 800. English ton-miles : 291 041 760.

Number of fractures { total : 11. per 10 000 000 tr.-km. or 6 250 000 train-miles : 31.18. per 1 billion tkm. or 612 0000 000 English ton-miles : 23.11.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails.*	28 %	72 %	6	5	...	5	6

E.	*Light rails.*
a) New clean fractures — with internal transverse fissure	...
a) New clean fractures — without internal transverse fissure	4
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the foot	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head — in the head	5
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head — in the web	2
d) Number of pieces rails are broken into	2 pieces : 10 3 pieces : 1

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years.			5 to 10 years.			10 to 15 years.			15 to 20 years.			More than 20 years.			The whole of the rails.			*Maximum axle load.*
	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
CZECHOSLOVAKIA. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*	6	531.4	7.0	28	456.9	38.1	53	368.0	89.5	129	515.7	155.4	1302	5 120.1	158.0	1518	6 992.1	134.9	
Medium	7	792.1	5.5	20	623.6	19.9	27	363.6	46.1	50	259.9	119.6	96	807.5	73.9	200	2 846.7	43.7	
Total	13	1 323.5	6.1	48	1 080.5	27.6	80	731.6	68.0	179	775.6	143.4	1398	5 927.6	146.6	1718	9 838.8	108.5	
B. Rails in tunnels. *Light*	...	3.7	...	...	2.6	...	...	1.4	...	...	2.4	...	2	4.5	277.8	2	14.6	84.9	
Medium	1	5.5	112.4	1	4.9	125.9	...	1.7	...	...	0.7	...	...	2.8	...	2	15.6	79.3	
Total	1	9.2	67.3	1	7.5	82.4	...	3.1	...	...	3.1	...	2	7.3	170.7	4	30.2	82.0	
C. The whole of A and B. *Light*	6	535.1	7.0	28	459.5	37.9	53	369.4	89.2	129	518.1	154.7	1304	5 124.6	158.1	1520	7 006.7	134.8	12.8-15.7
Medium	8	797.6	6.2	21	628.5	20.8	27	365.3	45.9	50	260.6	119.2	96	810.3	73.6	202	2 862.3	43.9	16.8
Total	14	1 332.7	6.5	49	1 088.0	28.0	80	734.7	67.7	179	778.7	142.8	1400	5 934.9	146.6	1722	9 869.0	108.4	

Number of { train-miles : 146 740 690.
English ton-miles : 33 210 355 530.

Number of fractures { total : 1 722.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 72.9.
per 1 billion tkm. or 612 000 000 English ton-miles : 31.7.

	Percentage of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m. (1 in 100).
D. *Light rails*	58.4	41.6	838	362	320	1 058	462
Medium rails	65.3	34.7	141	35	23	185	17
		Total	982	397	343	1 243	479
		Miles of single track of each class.	6 165.9	3 703.1		7 173.3	2 695.8

		Light rails.	*Medium rails.*
E. *a*) New clean fractures	with internal transverse fissure	267	31
	without internal transverse fissure	341	29
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	400	34
	in the head	178	43
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	334	65
d) Number of pieces rails are broken into		...	...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	Length of single track of this class.	Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
TURKEY. State Railways.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels:																			
Light.	1	680.4	0.91	5	638.8	4.9	...	88.9	...	5	248.6	12.5	32	1 118.5	17	43	2 775.2	12.4	17.2

Number of { train-miles : 5 938 074. English ton-miles : 1 958 375 020.

Number of fractures { total : 43. per 10 000 000 tr.-km. or 6 250 000 train-miles : 44.99. per 1 billion tkm. or 612 000 000 English ton-miles : 13.43.

	Number of fractures in the part: covered by the fishplates.	clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ⩽ 800 m. (40 chains) radius: Lower rail.	Higher rail.	on a rising or falling gradient: ⩽ 10 mm. per m. (1 in 100).	> 10 mm. per m (1 in 100).
D. *Light rails* . . .	20	23	25	...	18	43	...

		Light rails.
E. *a)* New clean fractures	with internal transverse fissure	21
	without internal transverse fissure	...
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	10
	in the head	12
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	...
d) Number of pieces rails are broken into		...

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
URUGUAY.		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
The Central Uruguay Railway Company of Montevideo.																			
A. Rails outside tunnels. *Light.*	1	1 006.0	0.6	...	...	...	...	...	...	...	...	...	17	1 006.0	10.6	18	1 006.0	11.2	15.5

	Number of fractures in the part: covered by the fishplates.	Number of fractures in the part: clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius. (including 40 chs.)	on curves of ≤ 800 m. (40 chains) radius (excluding 40 chs. radius). Lower rail.	on curves of ≤ 800 m. (40 chains) radius (excluding 40 chs. radius). Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100).	on a rising or falling gradient: > 10 mm. per m. (1 in 100).
D. *Light rails*	5	13	7	5	6	11	7
	Miles of single track of each class.		778.6	327.4		402 0	604

		Light rails.
E. *a)* New clean fractures	with internal transverse fissure	...
	without internal transverse fissure	10
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	5
	in the head	2
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	1
d) Number of pieces rails are broken into		2 pieces : 17 3 pieces : 1

NAMES OF ADMINISTRATIONS AND DESCRIPTION OF RAILS.	AGE OF RAILS: Less than 5 years. Number of fractures.	Less than 5 years. Length of single track of this class.	Less than 5 years. Number of fractures per 1 000 km. or per 625 miles.	5 to 10 years. Number of fractures.	5 to 10 years. Length of single track of this class.	5 to 10 years. Number of fractures per 1 000 km. or per 625 miles.	10 to 15 years. Number of fractures.	10 to 15 years. Length of single track of this class.	10 to 15 years. Number of fractures per 1 000 km. or per 625 miles.	15 to 20 years. Number of fractures.	15 to 20 years. Length of single track of this class.	15 to 20 years. Number of fractures per 1 000 km. or per 625 miles.	More than 20 years. Number of fractures.	More than 20 years. Length of single track of this class.	More than 20 years. Number of fractures per 1 000 km. or per 625 miles.	The whole of the rails. Number of fractures.	The whole of the rails. Length of single track of this class.	The whole of the rails. Number of fractures per 1 000 km. or per 625 miles.	*Maximum axle load.*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
JUGOSLAVIA. State Railways. (*)		Miles.			Miles.			Miles.			Miles.			Miles.			Miles.		English tons.
A. Rails outside tunnels. *Light*	56	522.0	67	80	502.1	99	28	311.9	56	60	323.7	120	1035	2 635.3	244	1259	4 295.0	182	13.8 - 17.7
Medium	17	362.9	29	7	311.3	14	2	11.8	105	12	180.8	41	54	209.4	160	92	1 076.2	53	14.8 - 17.7
Total	73	884.9	51	87	813.4	76	30	323.7	58	72	504.5	89	1089	2 844 7	238	1351	5 371.2	156	
B. Rails in tunnels. *Light*	...	8.1	...	2	3.7	333	3	5.0	375	1	2.5	250	1	6.2	100	7	25.5	171	13.8
Medium	3	3.7	500	...	1.9	...	...	...	...	...	1.2	...	2	7.5	167	5	14.3	217	14.8 - 17.8
Total	3	11.8	158	2	5.6	222	3	5.0	375	1	3.7	167	3	13.7	136	12	39.8	188	
C. The whole of A and B. *Light*	56	530.1	66	82	505.8	101	31	316.9	61	61	326.2	116	1036	2 641.5	244	1266	4 320.5	182	[illegible]
Medium	20	366.6	34	7	313.2	14	2	11.8	105	12	182.0	41	56	216.9	160	97	1 090.5	56	
Total	73	896.7	53	89	819.0	68	33	328.7	62	73	508.2	89	1092	2 858.4	237	1363	5 411.0	157	

Number of { train-miles : 44 066 000.
English ton-miles : 11 810 330 800.

Number of fractures { total : 1 363.
per 10 000 000 tr.-km. or 6 250 000 train-miles : 192.
per 1 billion tkm. or 612 000 000 English ton-miles : 70.

	Percentage of fractures in the part: covered by the fishplates.	Percentage of fractures in the part: clear of the fishplates.	NUMBER OF FRACTURES: on straight lines or curves of > 800 m. (40 chains) radius.	on curves of ≤ 300 m. (40 chains) radius: Lower rail.	on curves of ≤ 300 m. (40 chains) radius: Higher rail.	on a rising or falling gradient: ≤ 10 mm. per m. (1 in 100).	on a rising or falling gradient: > 10 mm. per m. (1 in 100).
D { *Light rails.*	36.8	56.1	897	197	172	1 122	144
Medium rails	4.4	2.7	65	23	9	74	23
		Total	962	220	181	1 196	167
		Miles of single track of each class.	4 183.8	1 227.2		3 940.0	471.0

		Light rails.	*Medium rails.*
E. *a)* New clean fractures	with internal transverse fissure	493	34
	without internal transverse fissure	315	19
b) Fractures with much rusted old part, extending to the outer surface of the foot or the head	in the foot	227	19
	in the head	179	20
c) Fractures with much rusted old part, *not* extending to the outer surface of the foot or the head	in the web	52	5
d) Number of pieces rails are broken into		...	...

(*) Standard gauge lines.

NOTE.

As shown by the heading, page 202, the above statistics of rail breakages as well as those published in the December 1935 and January 1936 numbers of the *Bulletin*, apply to the combined years 1933 and 1934, whereas formerly they were drawn up for a single calender year.

In this connection, we wish to draw the attention of our readers to the fact that all Railways have not adopted the same method when entering the track mileages. Whereas some Administrations have doubled these mileages, others — such as the French Railways — have shown only the *actual* mileages.

For the sake of uniformity and greater accuracy, we wish to recommend to the Affiliated Administrations, when filling in the statistical tables for the combined years 1935-1936, to double — or cumulate — the « length of single track » in service, so as to make possible a comparison between the figures representing the « number of fractures » and « number of fractures per 1 000 km. or 625 miles », with those of previous statistics relating to one single year.

MISCELLANEOUS INFORMATION.

[621. 132 4 (.42)]

London Midland & Scottish Railway orders for 369 locomotives.

(The Railway Gazette.)

In the afternoon of December 20, the London Midland & Scottish Railway Company announced that it had placed contracts amounting to £ 2 800 000 for 369 steam locomotives and 270 passenger carriages, embracing two of the items of work included in the programme of reconstruction and improvement under the Government Guaranteed Loan authorised by the Railways (Agreement) Act,, which received the Royal Assent that day. The list of works to be undertaken by the company is set out in the first Schedule to the Act, and the contracts now placed are in respect of paragraphs 3 and 4. The orders for the new locomotives have been placed with the following firms :

227 4-6-0 mixed traffic tender engines with Sir W. G. Armstroug Whitworth & Co. (Engineers) Ltd., Newcastle-on-Tyne.

69 2-8-0 freight tender engines with the Vulcan Foundry Ltd., Newton-le-Willows, Lancashire.

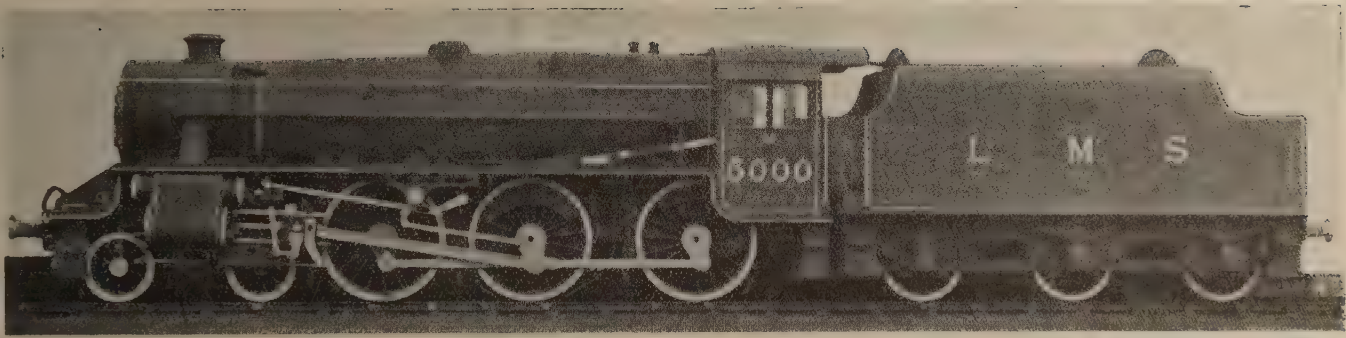
73 2-6-4 passenger tank engines with the North British Locomotive Co. Ltd., Glagow.

Apart from the additional employment caused by the construction of these locomotives and carriages, the work will involve the use of some 40 000 tons of steel and 5 000 tons of non-ferrous metal, which will provide additional employment in the production of the raw and semi-manufactured materials required.

All the new locomotives will be of the two-cylinder type. The mixed traffic engines are for the working of both express passenger and freight trains; the 2-8-0 freight tender engines will be used for the working of through mineral trains, and the 2-6-4 passenger tank locomotives for suburban services. Eight of the last mentioned locomotives are at present being built at the company's works at Derby and it is the first of this series No. 2537 that is illustrated hereafter.

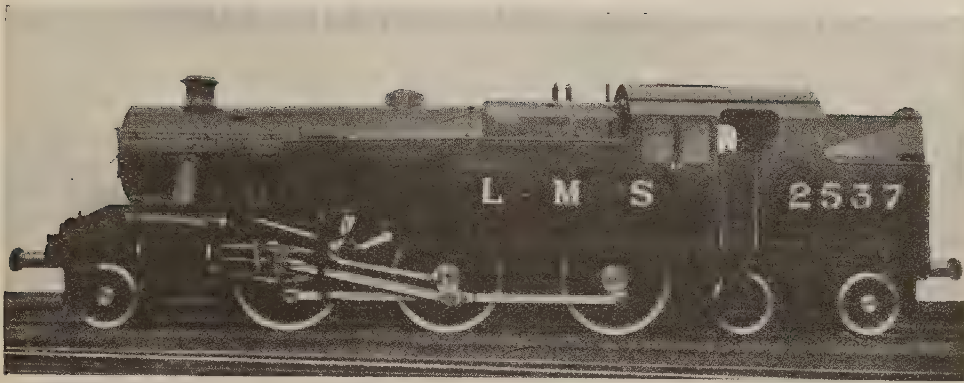
The following are the leading dimensions of the three classes of locomotives covered by the new contracts :

	4-6-0 *Mixed traffic.*	2-8-0 *Heavy freight.*	2-6-4 *Passenger tank.*
Cylinders, diameter	18 1/2 in.	18 1/2 in.	19 5/8 in.
Piston stroke	28 in.	28 in.	26 in.
Wheels, coupled, diameter	6 ft.	4 ft. 8 1/2 in.	5 ft. 9 in.
Wheelbase, coupled	15 ft.	17 ft. 3 in.	16 ft. 6 in.
» engine, total	27 ft. 2 in.	26 ft.	38 ft. 6 in.
Boiler, heating surface	Sq. ft.	Sq. ft.	Sq. ft.
Firebox	155.0	155	137
Tubes	1 425.8	1 308	1 031
Total (evaporative)	1 580.8	1 463	1 168
Superheater	256.2	235	185
Combined total	1 837.0	1 698	1 353



4-6-0 two-cylinder mixed traffic engine.

Two-cylinder 2-8-0 heavy freight locomotive.



Two-cylinder 2-6-4 type passenger tank engine.

	4-6-0 *Mixed traffic.*	2-8-0 *Heavy freight.*	2-6-4 *Passenger tank.*
Grate area	27.8 sq. ft.	27.8 sq. ft.	25.0 sq. ft.
Boiler pressure	225 lb.	225 lb.	200 lb.
Weight of engine and tender in working order	125 tons 5 cwt.	124 tons 12 cwt.	91 tons.
Water capacity of tender or tanks	4 000 gallons.	4 000 gallons.	2 000 gallons.
Coal capacity of tender or bunker	9 tons.	9 tons.	3 1/2 tons.
Tractive force (85 % b.p.)	25 455 lb.	32 438 lb.	24 670 lb.

The 4-6-0 and 2-8-0 type engines with tenders are the same in all respects as those already in service and the only real difference between the 2-6-4 tank engines and their predecessors is that the number of cylinders is reduced from three to two, with a corresponding re-arrangement of the cylinder dimensions. The regulator is located in the steam dome instead of in the smokebox as was done in the previous 2-6-4 type tank and 4-6-0 mixed traffic engines.

NEW BOOKS AND PUBLICATIONS.

[621. 13 (02]

SAUVAGE (E.), Honorary Chief Engineer, French State Railways, Laureate of the « Institut de France ». — **La machine locomotive** (*The locomotive engine*). — Practical text book on the construction and working of the locomotive, for drivers and firemen. — 9th edition. — One 8vo volume of 478 pages with 377 figures in the text. — 1935, Librairie Polytechnique Ch. Béranger, 1, Quai de la Grande-Bretagne, Liége. (Price, bound: 100 Belgian francs.)

Our readers need no introduction to this well known manual which, since its first appearance in 1894, has been much appreciated by the enginemen as a guide. The popularity of the work has been reflected by the successive editions issued to keep it abreast of the progress realised in locomotive practice.

The present volume is the 9th edition. The text follows the 8th edition of 1926 in the first nine chapters dealing with general matters, the boiler, mechanism, frame and wheels, various locomotive types, tenders, boilers, locomotive driving and shed practice.

The new features have been collected in 8 supplementary chapters which bring out very clearly the progress realised in recent years.

In the additional chapter on boilers, increased pressures, special firebox designs, tube blowers, new designs of blast pipes, and feed water heaters are dealt with. In the chapter devoted to the mechanism, valve gears for three cylinders and poppet valve gears are considered. The other supplementary chapters deal with crank axles, automatic couplings, articulated locomotives, boosters, running tests of locomotives and locomotive testing plants, recent designs of tenders, new brake equipment especially in connection with goods trains, reversible steam driven rakes, locomotive cab signals, etc...

If the title of the book shows that it is addressed more especially to the drivers and firemen, the engineer and builder will occasionally find in it information they are looking for, and will re-read the book with the greatest profit.

A. C.

[621. 131.2]

LÜBSEN (Dr.-Ing. W.). — **Die Verbesserung der Wirtschaftlichkeit der Dampflokomotive durch konstruktive Massnahmen zur Senkung des Brennstoffverbrauches** (*Improved locomotive efficiency by constructional means resulting in lower fuel consumption*). — One volume (6 5/16 × 9 7/16 inches) of 104 pages, with 25 figures. — Berlin, 1935. — Publisher: Julius Springer. (Price: 7.50 Rm. in Germany; 5.62 Rm. in other countries.)

The author sets out to draw up the financial balance sheet for the various improvements in the steam locomotive, introduced in recent years with a view to reducing fuel consumption. On the debit side he shows the capital cost, interest and amortization charges, maintenance expenditure, and other expenditures. On the credit side he gives the saving in overall efficiency.

In the fifty paragraphs of which his book is composed, the author, by means of the tests carried out on various railways, has got out this saving or if

need be the limits beyond which the economy of the equipment can become illusory.

The descriptive details have been reduced to the strict minimum, the reader in each case being referred to the technical press for more detailed investigations. This has enabled him to review most concisely the present state of evolution of the steam locomotive and to suggest possible further developments or tests required to form definite conclusions.

The book begins by dealing with the two important questions of mechanical firing and the use of pulverised coal as regards the conditions of use, the results of tests on the railways, the operating advantages and the final efficiency. Following the heat cycle of the locomotive he then deals with improvements in the boiler and compares the results obtained with Nicholson syphons, with those given by boilers with 6.80 m. = 22 ft. 4 in. tubes (Reichsbahn tests), special smoke tubes such as the Serve and the Ess, used on Scandinavian railways, and improved superheaters, as well as by raising the pressure of the normal type of boiler.

Other paragraphs deal with improvements on the mechanical side of the locomotive, such as compounding, improved valve gear, increased stroke of piston in piston valves, poppet valves, investigation into exhaust steam injectors and various feed water heaters, as well as improved blast pipes.

New types of locomotives, such as high pressure, and turbine locomotives with and without condensation, are also dealt with in detail. The author then deals with water treatment, rebuilding locomotives to obtain greater efficiency, and the effect of recent improvements on the design of new engines.

A very interesting paragraph demonstrates by means of diagrams the comparative financial value of the various improvements dealt with.

The author ends by expressing the opinion that the evolution of the steam locomotive is far from ended, and that the low thermal efficiency so frequently raised against it can be materially improved. Compared with its competitors the electric locomotive and the diesel locomotive, the steam locomotive is half or a third the cost for equal power, and relatively to the diesel, much easier to maintain, so that, provided the cost of coal is favourable, the steam locomotive definitely remains the best from an economic point of view.

A. C.

[385. (01 (.6)]

HONORE (Maurice), Ingénieur des Arts et Manufactures. — **Transsaharien et Transafricain** (*The Trans-Saharan and Trans-African Railways*). — Lecture given before the *French Colonial Institute*. — A pamphlet (10 1/2 × 7 1/4 inches), of 32 pages, with 7 maps. — Abstracted from the « Mémoires de l'Association Française pour le Développement des Travaux Publics », 8, rue Jean Goujon, Paris (8e).

The object of this lecture was to show the importance to the French African Colonies of building a Trans-Saharan Railway, and how this railway would lead to a rational Trans-African Railway.

The idea of building a railway across the Sahara is an old one and many schemes have been put forward. In 1928 an organisation was formed for studying a railway across the Sahara, to link up Northern Africa to French West Africa. After the possible locations had been surveyed, a report was drawn up and its conclusions adopted by the Commission appointed to exa-

mine the proposal. No progress in the matter, however, has since been made. The author has used to a large extent the information collected by the Investigating Organisation.

The essential object of the Trans-Saharan railway is to provide communication between Northern and French West Africa. At the present time the Northern territories have been developped very considerably, largely through the transport facilities provided. In the Southern territories (French West Africa) the development has been almost entirely on the coast. It has barely started in the Niger region which is still far from being served by the narrow gauge lines which start from the coast. The Nigerian hinterland has great possibilities from the agricultural and stock raising points of view, but suffers from lack of communications. Even if connected to the coast, its products would have a long sea voyage to get to France or the Northern territories. The Trans-Saharan would give direct inland communication between the Mediterranean and tropical zones, and would make it easy to organise those exchanges of products the need for which is being felt more and more.

The author refutes the objection that the line, which would run through the Sahara desert, would bring no traffic, by comparing it with the Atlantic shipping services. As regards the danger from sand burying it, he quotes the Trans-Caspian and Trans-Australian Railways which cross 800 km. (500 miles) and 1 700 km. (1 056 miles) of desert respectively, including sand hills, whereas there are several favourable locations for the Trans-Saharan.

As regards the method of connecting the territories, Mr. Maurice Honoré gives conclusive reasons why the railway is the only one that can meet requirements.

Three locations are suggested. After briefly examining them, the author considers the most western the best for the following reasons : shortest length (3 535 km. = 2 200 miles), easy gradients (1 in 200), easy and fast to build, and lowest costs of construction.

The line would be simple to build as there would be practically no structures.

The method of operation would be to run few heavy (3 000-ton) trains at high speed. The rates would be very low.

As regards traction : the shortage of water must be remembered so that diesel-electric locomotives would appear to be the best solution.

* * *

The Trans-Saharan would also form the beginning of the Trans-African Railways.

Several schemes have been got out for connecting the Cape and the Mediterranean. The author shows the superiority of a Trans-African Railway starting from Algeria. Not only would it serve the immense French, Belgian, British, and Portuguese possessions but would put them into almost direct communication with their home countries.

This clear, sound, and objective review throws much light on a question which interests other countries besides France.

E. M.

[621. 131.2]

LIPETZ (A. I.), Consulting Engineer, American Locomotive Company. — **Tractive effort of steam Locomotives (Locomotives Ratios. — II).** — A pamphlet (8 1/4 × 11 1/32 in.) of 25 pages with 25 figures. Abstracted from the *Proceeding of the American Society of Mechanical Engineers.*

In a paper given in 1932 before the American Society of Mechanical Engineers und reviewed in the April 1935 number of the *Bulletin of the Railway*

Congress, Mr. Lipetz put forward new formulæ for calculating the indicated power and the tractive effort of modern steam locomotives, in terms of the rate of evaporation as defined by Cole, the driving wheel diameter, and a constant depending upon the speed. This method has been checked for certain American locomotives, the calculated values agreeing with the results of tests.

In the discussion on the paper, certain criticisms were made, amongst others by Mr. Vincent whose remarks we also published in the same number of the *Bulletin.*

Mr. Vincent showed that Mr. Lipetz's formulæ did not give accurate enough results for large-cylindered locomotives with a relatively low ratio of heating surface to cylinder volume.

Mr. Lipetz, in this paper, deals with the influence of cylinder dimensions and shows that for locomotives with unusual relative boiler and cylinder dimensions, the original moduli must be modified.

These altered formulæ have also been checked in the case of some locomotives with relatively large cylinders. The author is thus led to proposing a new modulus, which he calls the locomotive characteristic and which depends on the rate of evaporation defined by Cole, the pressure, and the cylinder volume. The 1932 moduli can be used for certain values of this characteristic, but for others the modified moduli should be employed.

Mr. Lipetz's paper will be read with interest, in conjunction with those previously reproduced in the *Bulletin,* and the discussion which followed its presentation before the American Society of Mechanical Engineers. The author, in replying, stresses the fact that his method only applies and has only been checked for the current types of American locomotives with two cylinders with simple expansion, using superheated steam, and must not be applied to compound locomotives of the European type nor to special types of locomotives.

A. C.

[385 (06. 111]

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ISSUED BY THE

Permanent Commission of the International Railway Congress Association,

74, rue du Progrès, BRUSSELS.

XIIIth SESSION — PARIS (1937)

LIST OF QUESTIONS

for discussion

WITH THE NAMES OF THE REPORTERS.

Ist SECTION : WAY AND WORKS.

QUESTION I.

The construction of modern track to carry heavy loads at high speeds, and methods of modernising old track for such loads and speeds. Facing points which can be taken at high speeds.

Reporters :

Belgium and Colony, Luxemburg, Netherlands and Colonies, Denmark, Norway, Sweden, Finland, Germany, Poland, Austria, Hungary, Switzerland :

Mr. LEMAIRE, directeur du service de la voie, à la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Brussels.

France and Colonies, Spain, Portugal and Colonies, Italy, Czechoslovakia, Bulgaria, Rumania, Jugoslavia, Greece, Turkey, Egypt :

Mr. FLAMENT, ingénieur en chef adjoint des travaux et de la surveillance, Compagnie du Chemin de fer du Nord français; 18, rue de Dunkerque, Paris (10e).

Japan, Great Britain, Dominions and Colonies, America, China :

Dr. KIKUMATSU HIRAI, director of maintenance and improvement, Japanese Government Railways, Tokyo,

and

Dr. TAKAJI YAMADA, chief of railway research office, Japanese Government Railways, Tokyo.

QUESTION II.

Use of welding :

1. to obtain extra-long rails;

2. in manufacturing and repairing points and crossings.

a) Results obtained by using extra-long rails.

Methods used to ensure safe expansion of the rails and anchoring of the track.

b) Technical and financial results shown by welding points and crossings.

Reporters :

Germany, Belgium and Colony, Luxemburg, Netherlands and Colonies, Denmark, Norway, Sweden, Finland, Poland, Austria, Hungary, Switzerland :

Herr Müller, Reichsbahndirektor, Deutsche Reichsbahn Gesellschaft; 35, Voss-Strasse, Berlin W. 8.

France and Colonies, Spain, Portugal and Colonies, Italy, Czechoslovakia, Bulgaria, Rumania, Jugoslavia, Greece, Turkey, Egypt :

Mr. Ridet, ingénieur en chef adjoint de la voie et des travaux à la Compagnie des Chemins de fer de l'Est français; 23, rue d'Alsace, Paris (10e).

Great Britain, Dominions and Colonies, America, China, Japan :

Mr. Ellson, chief engineer, Southern Railway; Waterloo Station, London S. E. 1.

QUESTION III.

Methodical and periodical maintenance of :

1. metal bridges;

2. signals;

3. metal supports carrying the contact wire on electric railways.

Organisation. — Working methods. — Materials used.

Reporters :

Spain, Portugal and Colonies, France and Colonies, Italy, Czechoslovakia, Jugoslavia, Bulgaria, Rumania, Greece, Turkey, Egypt :

Mr. Mendoza, sous-chef du service du matériel fixe, voies et travaux de la Compagnie des Chemins de fer du Nord de l'Espagne, Madrid.

Great Britain, Dominions and Colonies, America, China and Japan :

Mr. Fraser, engineer (Scotland) London & North Eastern Railway; 23, Waterloo Place, Edinburgh.

Netherlands and Colonies, Germany, Belgium and Colony, Luxemburg, Denmark, Norway, Sweden, Finland, Poland, Austria, Hungary, Switzerland :

Mr. Mundt, ingénieur en chef des ponts du service de la voie des Chemins de fer néerlandais, Utrecht.

2nd SECTION : LOCOMOTIVES AND ROLLING STOCK.

QUESTION IV.

Evolution of the rail motor car as regards its construction, and special investigation into the transmission and brake questions.

Comparative methods of testing railcars.

Detailed investigation into the costs of railcars and the methods of reducing them.

Reporters :

France and Colonies, Belgium and Colony, Luxemburg, Netherlands and Colonies, Great Britain, Dominions and Colonies, Spain, Portugal and Colonies, Italy :

Mr. Dumas, ingénieur en chef adjoint du matériel et de la traction de la Compagnie du Chemin de fer du Nord français; 78, rue des Poissonniers, Paris (18e), and

Mr. Levy, chef du service du matériel et de la traction des Chemins de fer de l'Etat français; 44, rue de Rome, Paris.

Germany, Poland, Denmark, Norway, Sweden, Finland, Austria, Hungary, Switzerland, Czechoslovakia, Jugoslavia, Bulgaria, Rumania, Greece, Turkey, Egypt:

Herr Stroebe, Reichsbahndirektor, Deutsche Reichsbahn Gesellschaft; 35, Voss-Strasse, Berlin W. 8.

America, China, Japan :

Mr. Wanamaker, electrical engineer, Chicago, Rock Island & Pacific Railway; Chicago, Ill.

QUESTION V.

Recent improvements in steam locomotives of the usual type and tests of new designs (high-pressure reciprocating locomotives and turbine locomotives) as regards construction, quality of materials used, efficiency, working conditions, maintenance and financial results.

Testing locomotives at locomotive experimental stations, and in service with dynamometer cars and brake locomotives.

Reporters :

France and Colonies, Germany, Belgium and Colony, Luxemburg, Netherlands and Colonies, Denmark, Norway, Sweden, Finland, Poland, Austria, Hungary, Switzerland :

Mr. Parmantier, ingénieur en chef adjoint du matériel de la Compagnie des Chemins de fer de Paris à Lyon et à la Méditerranée; 20, boulevard Diderot, Paris (12e), and

Mr. Dugas, ingénieur en chef du service des machines des Chemins de fer P. O.-Midi; 41, boulevard de la Gare, Paris (13e).

Great Britain, Dominions and Colonies, America, China and Japan :

Mr. Gresley, chief mechanical engineer, London & North Eastern Railway; King's Cross Station, London, N. 1.

Italy, Spain, Portugal and Colonies, Czechoslovakia, Jugoslavia, Bulgaria, Rumania, Greece, Turkey, Egypt :

Mr. Mascini, inspecteur en chef supérieur, service du matériel et de la traction, Chemins de fer de l'Etat italien, Florence.

QUESTION VI.

Methods and devices used, in connection with electric traction, to save current between the supply side of the power station and the driving wheels (feeders, substations, tractors), and in particular the use of mercury rectifiers.

Reporters :

Switzerland, France and Colonies, Spain, Portugal and Colonies, Italy, Belgium and Colony, Luxemburg, Netherlands and Colonies, Egypt :

Mr. Eggenberger, ingénieur en chef de la division de l'électrification des Chemins de fer fédéraux suisses, Berne.

Austria, Germany, Denmark, Norway, Sweden, Finland, Poland, Hungary, Czechoslovakia, Jugoslavia, Bulgaria, Rumania, Greece, Turkey :

Herr Kaan, Ministerialrat, Direktor der Elektrisierungsdirektion der Osterreichischen Bundesbahnen; I., Schwarzenbergplatz, 3, Vienna;

Great Britain, Dominions and Colonies, America, China, Japan :

Mr. C. E. Fairburn, electrical engineer, London Midland & Scottish Railway; Euston Station, London, N. W. 1.

3rd SECTION : WORKING.

QUESTION VII.

Economical operation of the main line system's secondary lines.
Various methods adopted to adjust the operating facilities, safety measures, and station organisation to the volume of traffic.

Reporters :

France and Colonies, Belgium and Colony, Luxemburg, America, , China and Japan :

Mr. Grandjean, ingénieur en chef de l'exploitation des Chemins de fer d'Alsace et de Lorraine; 3, boulevard du Président Wilson, Strasbourg,
and

Mr. Gilmaire, ingénieur principal du service central de l'exploitation de la Compagnie des Chemins de fer P. O.-Midi; 1, place Valhubert, Paris (13e).

Italy, Spain, Portugal and Colonies, Switzerland, Austria, Hungary, Czechoslovakia, Jugoslavia, Bulgaria, Rumania, Greece, Turkey, Egypt :

Mr. Palmieri, inspecteur en chef supérieur, service du mouvement, Chemins de fer de l'Etat italien, Rome.

Sweden, Norway, Denmark, Great Britain, Dominions and Colonies, Germany, Finland, Poland, Netherlands and Colonies :

Mr. Emers, inspecteur en chef supérieur du service de l'exploitation, Direction générale des Chemins de fer de l'Etat suédois, Stockholm.

QUESTION VIII.

Application of rational organisation (planning) to the transport of goods,
especially in connection with :

1. the functions and internal working of shunting yards;
2. the provision of inter-yard connections;
3. the estimation of the probable traffic to be dealt with, and the provision of the trains required;
4. the information to be given to the consignees;
5. the acceleration of the turn-round of empty stock;
6. the use of containers and rail-road wagons.

Reporters :

Germany, Poland, Denmark, Norway, Sweden, Finland, Austria, Hungary, Czechoslovakia, Jugoslavia, Bulgaria, Rumania, Greece, Turkey :

Dr. Baumann, Reichsbahndirektor und Mitglied der Hauptverwaltung der Deutschen Reichsbahn Gesellschaft; 35, Voss-Strasse, Berlin W. 8.

Great Britain, Dominions and Colonies, America, China, Japan :

Mr. Barrington-Ward, superintendent, Western Section, London & North Eastern Railway; Liverpool Street Station, London E. C. 2.

Belgium and Colony, Luxemburg, Netherlands and Colonies, France and Colonies, Spain, Portugal and Colonies, Italy, Egypt :

Mr. Colle, ingénieur au service de l'exploitation, Société Nationale des Chemins de fer belges; 17, rue de Louvain, Bruxelles.

QUESTION IX.

Results obtained from the automatic and distant operation of signals and points, and from locomotive cab signals.

Reporters :

France and Colonies, Great Britain, Dominions and Colonies, Belgium and Colony, Luxemburg, America, China and Japan :

Mr. Tuja, ingénieur en chef de l'exploitation, Chemins de fer de Paris à Lyon et à la Méditerranée; 20, boulevard Diderot, Paris (12e),

and

Mr. Lemonnier, chef adjoint de l'exploitation, Chemins de fer de l'Etat français; 13, rue d'Amsterdam, Paris.

Poland, Germany, Netherlands and Colonies, Norway, Sweden, Finland, Denmark, Austria, Hungary, Czechoslovakia :

Mr. Miszke, ingénieur, directeur du bureau des études et des projets au Ministère des communications de Pologne; 14, rue Langiewicza, Warsaw.

Italy, Switzerland, Jugoslavia, Bulgaria, Rumania, Greece, Turkey, Egypt, Spain, Portugal and Colonies :

Mr. Bellomi, inspecteur en chef supérieur à la Direction Générale, service des travaux et des constructions, Chemins de fer de l'Etat italien; Piazza della Croce Rossa, Rome,

and

Mr. Minucciani, inspecteur principal, Service du matériel et de la traction, Chemins de fer de l'Etat italien; Bussoleno (Italy).

4th SECTION : GENERAL.

QUESTION X.

Effects of the world crisis and road competition on the railway position. Corresponding changes in railway commercial policy.

Reporters :

All main-line Railways affiliated to the International Railway Union (U. I. C.) :

Herr von Beck, Reichsbahndirektor und Mitgled der Hauptverwaltung der Deutschen Reichsbahn Gesellschaft; 35, Voss-Strasse, Berlin W. 8,

and

Dr. Cottier, secrétaire général des Chemins de fer fédéraux suisses, Berne.

All secondary Railways :

Mr. La Valle, inspecteur en chef de vigilance, Inspectorat général des Chemins de fer, tramways et automobiles d'Italie, Rome,

and

Mr. MELLINI, inspecteur supérieur de vigilance, Inspectorat général des Chemins de fer, tramways et automobiles d'Italie, Rome.

Main-line Railways of all countries except those affiliated to the International Railway Union (U. I. C.) :

Mr. ASHTON DAVIES, chief commercial manager, London Midland & Scottish Railway, Euston House; Seymour Street, London N. W. 1.

QUESTION XI.

Selection, orientation, and instruction of railway staff.

Reporters :

Poland, Germany, Netherlands and Colonies, Denmark, Norway, Sweden, Finland :

Mr. WOJCIECHOWSKI, ingénieur, chef du bureau psychotechnique au Ministère des communications de Pologne, Warsaw.

Czechoslovakia, France and Colonies, Belgium and Colony, Luxemburg, Switzerland, Austria, Hungary, Jugoslavia, Bulgaria, Rumania, Greece, Turkey :

Mr. HONDL, directeur des services du personnel, Ministère des Chemins de fer de Tchécoslovaquie, Prague.

Italy, Spain, Portugal and Colonies, Great Britain, Dominions and Colonies, America, China, Japan, Egypt :

Mr. LO BALBO, directeur de l'exploitation, Compagnie générale des tramways piémontais, Saluzzo (Italy).

5th SECTION : LIGHT RAILWAYS AND COLONIAL RAILWAYS.

QUESTION XII.

Co-ordination of operation as between main-line and light railways.

Reporters :

France and Colonies, Great Britain, Dominions and Colonies, America, Egypt, China and Japan :

Mr. DELILLE, directeur de la Société générale des Chemins de fer économiques de France; 4, Cité de Londres, Paris (9e).

Countries of Continental Europe and Colonies, except France :

Mr. BELMONTE, chef de service, Chemins de fer de l'Etat italien, Service commercial; Piazza della Croce Rossa, Rome,

and

Mr. TOSTI, chef de service, Chemins de fer de l'Etat italien, Service du personnel et des affaires générales; Piazza della Croce Rossa, Rome.

QUESTION XIII.

Specifications for the fixed plant of railways with light traffic, intended to prevent the use of unnecessarily expensive track equipment, and generally to give economical working.

Reporters :

Countries of Continental Europe and their Colonies, Egypt :

Mr. Svoboda, ingénieur, conseiller technique au Ministère des Chemins de fer de Tchécoslovaquie, Département VI/5; Prague II.

Great Britain, Dominions and Colonies, America, China, Japan :

Mr. Van Noorbeeck, directeur des voies et travaux à la Société nationale des Chemins de fer vicinaux de Belgique; 14, rue de la Science, Brussels.

MONTHLY BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS ASSOCIATION
(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES : 74, RUE DU RROGRÈS, BRUSSELS.

Yearly prepaid subscription { **Belgium . . . . . 70 Belgas** / **Other countries . . 75 Belgas** } including postage

Price of this single copy : 8 Belgas (not including postage).

(1 Belga = 5 Belgian francs.)

Subscriptions and orders for single copies (January 1931 and later editions) to be addressed to the General Secretary, International Railway Congress Association, 74, rue du Progrès, Brussels (Belgium).

Orders for copies previous to January 1931 should be addressed to Messrs. Weissenbruch & Co. Ltd., Printers, 49, rue du Poinçon, Brussels.

CONTENTS OF THE NUMBER FOR MARCH 1936.

CONTENTS.	Page.

CONTENTS *(continued).*	Page.
IX. NEW BOOKS AND PUBLICATIONS :	
Konjunktur und Luftverkehr *(Influence of the economic position on air traffic)*, by Carl PIRATH	361
Eisenbahntechnik : Zum hundertjahrigen Bestehen der Deutschen Eisenbahnen *(Railway technics : Commemoration of the Centenary of the German Railways)*. — Special number of the ZEITSCHRIFT DES VEREINES DEUTSCHER INGENIEURE *(Bulletin of the Union of German Engineers)*	361
X. MONTHLY BIBLIOGRAPHY OF RAILWAYS	31

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Works in connection with railway matters which are presented to the Permanent Commission are mentioned in the « Bulletin ». They are filed and placed in the library. If the Executive Committee deems it advisable they are made the subject of a special notice. Books and publications placed in the reading room may be consulted by any person in possession of an introduction delivered by a member of the Association. Books, etc., may not be taken away except by special permission of the Executive Committee.

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